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SECTION OF GEOLOGY AND MINERALOGY

DISCONTINUITIES IN THE STRATIGRAPHIC RECORD*

By John E. Sanders

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Introduction

Discontinuities, or "breaks" in the stratigraphic record, are important because: they record geographic changes, perhaps even vast movements in the earth; they were employed as "natural" boundaries in the type localities of our geologic systems; and they have been assigned great tectonic and chronologic significance in certain grand schemes of the earth's history. These "breaks" have also been responsible for creating traps in many large oil fields.

Further emphasis is not required here, for geologists everywhere are agreed on the necessity of paying careful attention to interruptions in the stratigraphic record, and they doubtless also agree that "breaks" may originate beneath the sea as well as by exposure of a sea bottom to subaerial erosion and its later resubmergence. Beyond this point, however, agreement ceases and inconsistency arises in the application of these ideas and in terminology. Debates over nomenclature have risen out of opposing philosophies on the sanctity of previous usage.

It is the thesis of this paper that, in spite of repeated emphasis placed on the importance of subaqueously formed breaks by Andrée (1908), Willis (1910), Grabau (1913), Sardeson (1914), Barrell (1917), Arnold Heim (1924; 1934), Heim and Seitz (1934), Twenhofel (1936), Shepard (1941), Krumbein (1942), Rich (1951), and many others, the existing terminology of stratigraphic breaks is inadequate and tends to obscure discontinuities of subaqueous origin. It is further contended that, as a result of this obscurity, errors and ambiguities have crept into nearly all existing paleogeographic maps.

Most of what follows has been expounded many times previously, but successive alterations in terminology have masked a clear statement of the variables involved in such a way that certain important ideas, although abundantly acknowledged, are but scantily applied.

Definitions of Unconformity

Consideration of definitions of unconformity illustrates the unsatisfactory state of present nomenclature.

*This paper, illustrated with lantern slides, was presented at a meeting of the Section on January 7, 1957.

Original usage. The first appearance of this term, according to my understanding of the first edition of Sir Charles Lyell's *Principles of Geology* (1830), must be credited to the Italian, Odoardi, who in 1761 used the adjective unconformable to describe the relationship between the Subapennine beds and the Older Apennine strata. Referring to Odoardi, Lyell wrote: "He pointed out that the strata of these two groups were *unconformable* [*sic*] and must have been the deposits of different seas at distant periods of time." At the time of this writing, unfortunately, I have been unable to consult the original reference cited by Lyell,* and I must therefore postpone for the present any conjecture as to what further specifications, if any, attended the original use.

Odoardi seems to have been forgotten by English-speaking geologists, and our present derivation of the word stems from the early 19th century British geologists, particularly James Hutton.

Other definitions. Perhaps typical of the widespread usage of the late 19th century in the United States and of persistent British usage was the definition of R. D. Irving (1888), who described unconformity as a structure produced by erosional truncation of older folded strata and their subsequent burial by younger strata. Irving is clear-cut on the subject of folding, for he speaks of "conformable" beds (parallel sequence) that contain erosional breaks and adds: "The word unconformity distinctly implies a lack of parallelism between the strata on opposite sides of the break, and moreover all true unconformities indicate folding as well as intervening erosion."

Irving's definition, which seems fairly close to the original, includes three parameters: (1) a break in deposition; (2) angularity between older and younger strata; and (3) subaerial erosion.

British geologists, as illustrated by Stamp's (1921) remark that "Unconformity ... rather suggests discordance of stratification and earth-movements of a more pronounced character," have rather consistently followed a usage like that of Irving and employ the root conformity to refer to the geometry of the strata.

Although Irving's specifications seem to me to be perfectly clear-cut and unambiguous, they were not so regarded by his American colleagues and immediate successors, who tended to enlarge the scope of the term unconformity, to change the emphasis of "conformity" away from geometric relationships toward erosional gaps in the record, and to propose new terms for several special, varietal relationships (FIGURE 1).

Joseph Le Conte (1904) applied unconformity to gaps in the geologic record caused by subaerial erosion, but he widened the term to include the configurations where beds above the unconformity are either parallel

*Sui Corpi Marini del Feltrino, 1761.

Subaerial erosion surface
Plutonic igneous or metamorphic rocks
NONCONFORMITY (Billings, 1942)
NON-CONFORMITY (Pirsson, 1915)
Subaerial erosion surface
UNCONFORMITY (Odoardi, 1761, in Lyell, 1830; R.D. Irving, 1888; Grabau, 1905; 1913; Stamp, 1921, etc.)
UNCONFORMITY (Blackwelder, 1909; Pirsson, 1915; Holmes, 1944; Gilluly, Waters, & Woodford, 1953; Longwell & Flint, 1955; etc.)
ANGULAR UNCONFORMITY (American usage)
CLINOUNCONFORMITY (Crosby, 1912)
DISKORDANZ (German usage)
UNCONFORMITY (Twenhofel, 1926; Shrock, 1948; Pettijohn, 1949)
Subaerial erosion surface
UNCONFORMITY (Lecompte, 1904; Crosby, 1912)
DISCONFORMITY (Grabau, 1905; 1913; Pirsson, 1915; etc.)
SUBAERIAL UNCONFORMITY (Twenhofel, 1936; Krumbein, 1942)
PARAUNCONFORMITY (Crosby, 1912)
Subaqueous surface of nondeposition
SURFACE OF NONDEPOSITION (Willis, 1910)
SUBMARINE UNCONFORMITY (Twenhofel, 1936; Krumbein, 1942)

FIGURE 1. Chart comparing various usages of unconformity and selected related terms.

or nonparallel to those below, and he added the prerequisite of unity of conditions of deposition during each of the two groups.

Blackwelder (1909) recognized that the scope of the term unconformity had been increased, but he adopted this broader usage owing to its general acceptance by geologists. Blackwelder also noted that another variety had been distinguished, namely one in which the contact separates rocks of wholly unlike origin, such as sedimentary rocks overlying igneous rocks.

Grabau (1905) proposed to restrict the term unconformity to the so-called structural type of unconformable relationship in which folding and erosion of the first-formed set of strata precede deposition of the younger set, in effect to return to the usage expressed by Irving. Grabau advanced the term disconformity for the parallel relationship that he also later (1913) designated a stratic unconformity.

Pirsson (1915) likewise emphasized subaerial erosion as a necessary component of the unconformity concept, but ignored Grabau and formalized the expanded concept of unconformity (previously expressed by Lecompte, Blackwelder, and others) by proposing the term nonconformity for cases where the two groups of rock are visibly different, the lower group being either nonstratified rocks or tilted stratified rocks. He observed that the latter type had been called angular unconformity by some geologists and, one might here add, unconformity by Grabau, Irving, and others. Pirsson applied the term disconformity as proposed by Grabau.

By this transmutation, one of Pirsson's classes of nonconformity (angularity unconformity *auctorum*) became synonymous with widespread earlier usage of unconformity itself.

Crosby (1912) emphasized that conformity indicates absence of erosion, whereas earlier workers had stressed geometric relationships. He also advocated use of unconformity as a general term for all erosional breaks.

Throughout all the foregoing modifications one thread runs clear: an unconformity signifies subaerial erosion. Even this fixed reference point disappeared with the further stretching of the term unconformity in the *Treatise on Sedimentation* (Twenhofel, 1926), where an unconformity is defined as a "surface of erosion or nondeposition separating two groups of strata." Twenhofel later elaborated on this theme and recognized two classes of unconformities, submarine and subaerial (Twenhofel, 1936).

Several shades of opinion on Twenhofel's modification have been expressed by more recent writers. Krumbein (1942) accepts Twenhofel's definition and types of unconformity. Shrock (1948) also adopts this usage, but Pettijohn (1949) is less decisive. Pettijohn states that "an *unconformity* is a surface separating two groups of strata. It is an erosion

surface, though the term has been extended to include surfaces of non-deposition."

Gilluly, Waters, and Woodford (1951) insist that erosion is necessary to the unconformity definition and add that the term conformable describes a sequence deposited continuously without erosional breaks. Holmes (1944) and Longwell and Flint (1955) emphasize that an unconformity means a lost interval caused by subaerial erosion.

All the aforementioned writers apply the words unconformity or unconformable in one way or another to describe interruptions in the deposition of sedimentary rocks, but a completely divergent view is expressed in R. L. Parker's translation of Paul Niggli's book (1954). Here angular relationship alone is emphasized, and the term unconformable is used to describe the contacts of intrusive masses that are not parallel to the layering of the adjacent country rock. Whatever their opinion on the various stratigraphic uses of the word unconformity, most American geologists would, I think, deplore this aberration of the word and would substitute "discordant" or "cross-cutting" where Niggli employed the term unconformable. It should be added here, however, that in German the term *Diskordanz* has the same stratigraphic significance that unconformity does in certain English-speaking quarters.

What, then, is an unconformity? Does the root conformable (therefore the opposite when prefixed by "un-") refer to parallelism of strata above and below a stratigraphic break or to sequences that lack breaks caused by subaerial erosion? Or does it refer to sequences that lack breaks of any kind? This matter will be considered further on a subsequent page.

Basis for Genetic Classification

Classification and nomenclature of discontinuities may be based on one of four factors, or on a combination of these: (1) geometry of surface of discontinuity and angular relationships of beds above to those below; (2) time elapsed during discontinuity; (3) maintainance of geographic continuity or lack of it; and (4) whether or not subaerial exposure has taken place. As I have already indicated, a major difficulty with existing terminology has been the attempt to include too many of these factors within a single term.

(1) *Geometry of surface of discontinuity and angular relationships of beds above to those below.* This has been a widely used first-order factor in the classification and nomenclature of discontinuities; in fact, nearly all terms have been erected on this basis. Unfortunately for the sake of precision, however, the fact that these configurations can originate in more than one way has not been widely appreciated. Consideration of examples including sedimentary rocks both above and below a surface of discontinuity reveals several possible geometric arrangements. The

sets of strata above and below the break may be parallel, and the surface of discontinuity smooth or irregular, or the strata below may not be parallel to those above. Without additional information, it is impossible to make further diagnoses of any of these configurations, for all may form alike subaerially or subaqueously, at least on the scale of the average outcrop.

As indicated by Krumbein (1942) and others, the occurrence of plutonic igneous masses or metamorphic rocks below sedimentary beds seems a reliable clue to an episode of extensive subaerial erosion that removed the cover from these rocks of typically deep-seated origin before subsequent burial by strata formed at or near the earth's outer surface.

A terminology that is frankly descriptive for all configurations except the last is therefore necessary because the geometry of an exposure may reveal nothing significant about the subaqueous or subaerial origin of the discontinuity. Wider study presumably would permit distinction, for example, between a mass of strata crumpled in subaqueous sliding or by large-scale tectonic movements, but if one is to have a scientific, operational approach to outcrop study not only for one's own use but for the guidance of students, it seems to me one has no other alternative than to adopt both a descriptive and a genetic terminology.

(2) *Time elapsed during discontinuity.* Most students of discontinuities agree that time elapsed does not constitute a reliable basis on which to construct a classification. They have specifically mentioned that the time elapsed may be long or short. Although Irving (1888) probably represents a widely held sentiment among geologists when he observes that unconformity means a long-continued interval of erosion, he specifies that unconformities vary in the length of their unrecorded intervals. Barrell (1917) is responsible for the distinction of breaks into "major" and "minor," based on the amount of time elapsed. He restricted the term disconformity to breaks large enough to cause faunal and floral changes in the rocks above and below, or of "formational value," and proposed the word diastem for smaller breaks the duration of which is too brief to be clearly indicated by faunal or floral change, but which might vary in time from "seasonal cessations of deposition to those which approach geologic epochs in duration" and which correspond "to a bed or series of beds" elsewhere. Modern stratigraphic usage (Schenck and Muller, 1941) no longer favors use of formations as corresponding to fixed time intervals, as was common in Barrell's time, so "formational value" loses its significance.

It may go against the psychological grain of many geologists to dismiss time concepts from the terminology of discontinuities, but I contend that such dismissal is warranted by the fact that data for determining time

elapsed are commonly not available, and that even where they are present they fail to provide a consistent basis for classification.

(3) and (4) *Maintainance of geographical continuity or lack of it versus presence or absence of subaerial exposure.* The remaining two choices will be considered together, as they are very much intertwined, and either provides a consistent basis for genetic classification and nomenclature. Where geographical continuity is made the first-order factor, subaerial exposure or lack of it plays a dual role. It becomes a first-order factor in some instances, and a second-order factor in others, depending upon its relation to geographical continuity. For example, if a discontinuity develops during continued submergence of a sea bottom, the subaqueous origin of the break is a second-order parameter because the larger, first-order geographical continuum (marine environment) is not interrupted. Submergence beneath the sea becomes a first-order factor, however, where inundation of a land surface causes a geographical change. Subaerial exposure of a sea bottom, on the other hand, is a first-order parameter (major geographical change); but subaerial exposure of a sediment face, a routine part of the regimen in many nonmarine environments, becomes a second-order factor where it falls within a realm of geographical continuity.

The other alternative simply employs subaerial exposure as its sole first-order parameter. This method cuts across geographical continuity, but maintains a consistent sedimentologic basis, that of subaerial exposure or the lack of it. As far as effect on the sediments is concerned, division into major classes of discontinuities based on origin by subaerial exposure or by subaqueous processes seems to me to be more significant, for subaerial exposure allows certain processes that cannot take place under water to operate on sediment (and vice versa) irrespective of geographical setting. Geometric relationships provide satisfactory second-order bases for subdivision in either scheme.

Proposed Terminology

In view of the foregoing, a new classification and nomenclature for stratigraphic discontinuities is proposed as follows (FIGURE 2). The term discontinuity is employed as a general one to refer to any interruption in sedimentation, whatever its cause or length. Various kinds of discontinuities are recognized on the basis of geometric configuration, for purely descriptive purposes: discordant discontinuity refers to those instances in which the older set of strata were tilted and beveled prior to deposition of the younger set; features of the discontinuity surface are not emphasized in these cases, but could be, if desired. Where strata above and below a discontinuity are parallel, the adjective concordant is used, as is an appropriate Greek prefix to describe the surface itself: trachydiscontinuity for those with irregular surfaces (Gr. *trachys*, rough)

FIGURE 2. Proposed nomenclature of discontinuities.

and leurodiscontinuity for those with regular surfaces (Gr. *leuros*, smooth, level). These terms have no exact parallels in existing nomenclature, as they are purely descriptive and can be applied at any outcrop on the basis of empirical observations.

Two groups of corresponding terms are devised for discontinuities the subaqueous or subaerial origin of which can be inferred: hydrodialeima refers to any break caused by subaqueous processes (Gr. *hydrias*, of water + *dialeima*, interval), and atmodialeima (Gr. *atmos*, cloud) to any break formed subaerially.

Previous usage for subaqueous breaks is considered unsatisfactory and is entirely rejected. Geometric subdivision, following the same method as used with the descriptive terms, is employed, but with hydrodialeima as the root word instead of discontinuity. A discordant hydrodialeima is a discontinuity formed subaqueously in which the lower strata have been disturbed and truncated before deposition of younger beds. Additional description of the surface itself is optional. Where strata above and below the break are parallel, the adjective concordant is applied, as before, and the same prefixes referring to rough or smooth surface, respectively, are attached, producing such formidable combinations as concordant trachyhydrodialeima and concordant leurohydrodialeima.

The remaining group of discontinuities includes all stratigraphic breaks caused by subaerial exposure, no matter what the length of the time of exposure. Geometric subdivisions that correspond to those of the preceding groups are made, and the familiar terms based on the root conformity are applied where reasonable approximations of original usage can be preserved. Thus, unconformity refers to subaerially caused breaks where strata below are discordant with those above, and disconformity to breaks caused by subaerial erosion in which beds above and below remain parallel. It is obvious that an unconformity may pass laterally into a disconformity after one leaves the belt of folding, which may be rather narrow, but this does not mean that the term unconformity should be extended to both relationships. Although, as pointed out by Crosby (1912), the etymology of Grabau's term is unfortunate, it was clearly defined and has been widely used without much modification. The terms evident disconformity and nonevident disconformity (Pirsson, 1915) have been used to describe surfaces of disconformity that are irregular and regular, respectively.

There remain those cases where plutonic igneous or metamorphic rocks underlie a subaerial erosion surface that is overlain by sedimentary strata. Such examples were included in half of the original definition of nonconformity (Pirsson, 1915), the other half being unconformity ("angular unconformity," clinounconformity, and the like) itself.

Should dispute arise over the advocated use of the "conformity" terms, it is recommended that in the interest of stabilized nomenclature they all be abandoned and completely replaced with the root word atmodialeima, in combination with discordant, concordant, trachy-, and leuro-, as previously applied to the first two groups.

Conclusion

I have taken on the onerous task of coining new words in an attempt to draw attention to an important category of geologic phenomena that has received insufficient attention in the past: breaks in deposition formed under water. I submit that the present confused nomenclature has failed to emphasize these and must be overhauled in the interest of accurate description and clear thinking in stratigraphy and paleogeography. If others find themselves in agreement, they must either be content to alter further the definitions of words that have been already expanded and contracted almost beyond recognition, or adopt new ones. The present paper is offered to those who prefer the latter alternative. Space limitations preclude further discussion of possible meanings of existing terms, criteria for recognition of the various kinds of discontinuities, or examples of them. These subjects will be treated at greater length elsewhere.

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SECTION OF PHYSICS AND CHEMISTRY

OPTICAL ACTIVITY, MOLECULAR SYMMETRY ELEMENTS, AND CONFIGURATION IN THE BIPHENYL SERIES*

By Kurt Mislow

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The phenomenon of enantiomerism and optical resolvability has long been accounted for in terms of the structure and geometry of molecules by the successful theory of van't Hoff and Le Bel.[1a,b,c] Since publication of this theory the main emphasis in stereochemistry has largely been on compounds having asymmetric centers, but it has also long been recognized[1a,b,c] that central asymmetry is not necessary for optical activity, a prediction borne out by the resolution of allenes and spiranes. The optical resolution of 6,6′-dinitro-2,2′-diphenic acid[2] has served as a further extension of theory, in providing the first demonstration that optical activity and resolvability are, on occasion, consequent upon restricted rotation and not predicated on the basis of type formula alone. Since then, conformational enantiomerism has been demonstrated in systems as structurally diverse as tri-o-thymotide,[3] 4-carboxy(2.2)paracyclophane,[4] and hexahelicene.[5]

In recent years we have carried out a program at New York University aimed at solving certain fundamental problems in stereochemistry. Some of these studies have been greatly facilitated, from the experimental point of view, by the incorporation of the biphenyl grouping into the molecular structure to be examined, but the results of these investigations can be extended and generalized to include systems of optically active substances not containing that grouping. Other studies have had as their aim the elucidation of the problem of absolute and relative configuration of biphenyls since, thus far, virtually no work seems to have been reported in this area on other than centrally asymmetric compounds. All of these diverse investigations, however, have had as their common vehicle the system of hindered and restricted biphenyls, and it is the highlights of these researches that I propose to present here.

Symmetry Criteria for Optical Activity and Inactivity: A Critical Re-examination

It is now generally conceded that molecular dissymmetry is a necessary condition for the optical activity of all fluid aggregates. The germinal idea that led to this recognition, and that may be regarded as marking the beginning of modern stereochemistry, was first expressed by Louis

*This paper, illustrated with lantern slides, was presented at a meeting of the Section on January 8, 1957.

Pasteur nearly a century ago.[6] The more precise formulation of this concept in terms of structural details[1a,b,c] has stimulated, in the course of the past seventy-five years, intensive efforts to refine and to extend the original picture. Thanks to the enormous volume of experimental findings accumulated by numerous investigators during that period, some general beliefs have emerged that bear on the relationship of resolvability and optical activity to molecular symmetry elements. Before discussing these, it seems appropriate to clarify the pertinent terminology.

A conformation is said to possess *reflection symmetry* if its mirror image, obtained by a symmetry operation of the second kind (reflection of the conformation, taken as a rigid system of points-in-space through a mirror-plane), can be converted into the original conformation by symmetry operations of the first kind alone (rotation and translation of the complete, rigid, points-in-space system); the last transformation is called *superimposition* on the mirror image. The possession of reflection symmetry can be expressed alternatively in the statement that the rotamer (conformation) possesses mirror-axes or *alternating axes of symmetry*, specifically points, planes, or 4*n*-fold alternating axes[7] of symmetry. These axes refer to rigid points-in-space systems, that is: the molecule as a whole is considered an assemblage of such points, and the rotations and reflection implied in the term "alternating axis" are performed on the same assemblage, with the positions of the points (atoms) remaining unaltered relative to one another. Reflection symmetry and alternating axis of symmetry are terms, therefore, that do not include the operation of rotamerization, that is, the movement relative to one another of the points-in-space (atoms). For example, *meso*-tartaric acid in conformation

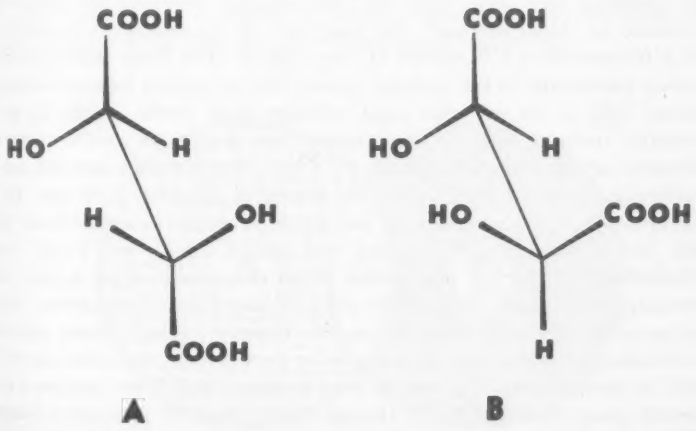

FIGURE 1.

A (FIGURE 1) has a twofold alternating axis (point of symmetry), whereas conformation *B* (FIGURE 1) does not possess reflection symmetry (alternating axes).

Conformations lacking reflection symmetry (alternating axes) are said to be *dissymmetric*. Dissymmetric molecules may, however, still retain simple symmetry axes;[8] thus 6,6′-dinitro-2,2′-diphenic acid and hexahelicene possess twofold symmetry axes, and tri-o-thymotide has a threefold axis of symmetry. *Asymmetry* refers to total lack of symmetry elements (other than the trivial onefold axis), as is the case for 4-carboxy-(2.2)paracyclophane and 6-nitro-6′-chloro-2,2′-diphenic acid.

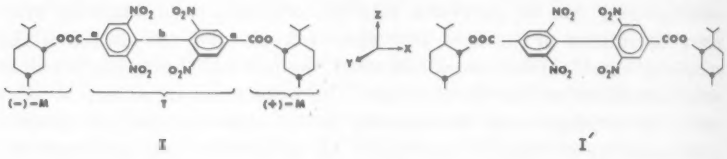

FIGURE 2.

Returning to the main argument, it has long been accepted that optical activity necessarily follows from molecular dissymmetry. Thus, it has recently been stated that, "if a molecule is at no time capable of possessing a plane or point of symmetry, the over-all activity of an appreciable number of such molecules is not zero"[9] and that "the absence of an alternating axis of symmetry is itself a sufficient criterion for optical activity."[10] However, this view has been contested;[11] from the fact that optical activity requires molecular dissymmetry it does not follow that the converse must also hold. We have recently provided the required evidence by demonstrating[12] the inactivity of (+)-menthyl (−)-menthyl 2,6,2′,6′-tetranitro-4,4′-diphenate (*I*, FIGURE 2). The bulky nitro groups prevent coplanarity of the biphenyl moiety (*T*), restricting rotation around central bond *b*. On the other hand, rotation about bonds *a* must be essentially free, so that the enantiomeric end groups (*M*) could assume virtually any position relative to *T*. If the phenyl groups are not perpendicular to one another, with two planes of symmetry (*XY* and *XZ*) contained in *T*, dissymmetry of the whole molecule is established by that fact alone; similarly, unless end groups (+)-*M* and (−)-*M* are oriented with respect to one another so as to possess either a point of symmetry or a plane of symmetry (*ZY*), *T* now being disregarded, dissymmetry of the whole molecule results. However, even if these partial conditions of highest reflection symmetry are fulfilled, the molecule will still be dissymmetric. The reason is to be discovered if we imagine *I* reflected along the long axis (*X*) through mirror plane *ZY* into mirror image *I′* (FIGURE 2). In order to achieve superimposition with respect to *T*, *I′* must be rotated about *X* through $\pi/2$. Again, in order to achieve super-

imposition with regard to the end groups *M*, disposed in the plane of symmetry or point of symmetry conformations, *I′* would have to be rotated about *X* through 2π or π, respectively. It is readily seen that *T* in *I′* will always be $\pi/2$ out of phase with respect to *T* in *I*; *I* is therefore dissymmetric. On the other hand, rotation through $\pi/2$ of *T alone* about bonds *a* in *I′* would make *I′* and *I* superimposable; *I′* can therefore rotamerize into *I*, and vice versa.

It cannot be too strongly emphasized that the last operation is *not* equivalent to the statement that *I* possesses a fourfold alternating axis of symmetry,[7] since the rotation last referred to is not participated in by the whole molecule but only by a portion of it.

Thus, although any given conformation of *I* cannot possibly be superimposed upon its mirror image *I′* through symmetry operations alone, it can nevertheless convert into *I′* through internal rotation. The molecular aggregate will therefore consist of molecules that can interconvert freely (condition of configurational purity). There should be a statistically equal number of the various enantiomeric conformations, that is, an enormous number of different transient *dl*-pairs (rotamers). The aggregate should accordingly be optically inactive (condition of optical inactivity), and the experimental evidence[12] bears out this prediction. At the same time, however, *no conformations possessing reflection symmetry are available to the system* (condition of dissymmetry). These structural considerations, together with the experimental evidence, conclusively vindicate our proposition: some dissymmetric molecules do not form optically active configurationally pure aggregates.

The demonstrated example is definitely not unique in type. Other than to note that molecule *I*, in addition to being dissymmetric, is also asymmetric, we do not recognize a property inherent in the structure that would single it out from any other dissymmetric molecule.

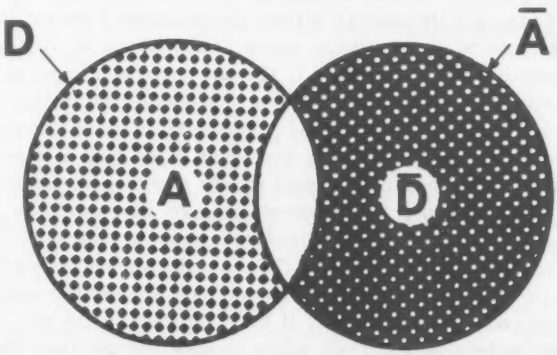

FIGURE 3.

Our proposition also includes transition states: dissymmetric transition states need not lead to optically active products.

There remains the problem of classification. Compound *I* (FIGURE 2) might possibly be regarded as a nonresolvable racemic mixture of conformational type, as exemplified by methylethylpropylamine, *cis*-1,2-dimethylcyclohexane and 2,2′-diphenic acid. However, the conformations in these examples can be assigned to two enantiomeric sets, separated in principle by an available symmetric high-energy form: in the quoted examples, (+)- and (−)-methylethylpropylamine by a plane-trigonal conformation having a plane of symmetry, (+)- and (−)-*cis*-1,2-dimethylcyclohexane by a boat conformation with a plane of symmetry, and (+)- and (−)-2,2′-diphenic acid by a planar conformation possessing plane and point of symmetry. In contradistinction, the conformations of *I* (FIGURE 2) and of similar compounds cannot be thus assigned, owing to the nonavailability of a symmetric conformation. It would not simplify the problem of classification to consider *I* a *meso*-diastereomer, since *meso*-compounds possess low-energy symmetric conformations (for example, conformation *A*, FIGURE 1), whereas *I* does not.

Our results now require a restatement of conditions relating resolvability, optical activity and dissymmetry, as follows: (1) molecular dissymmetry is a necessary but not a sufficient condition for resolvability and optical activity; (2) optical inactivity and nonresolvability are necessary but not sufficient conditions for molecular symmetry; (3) molecular symmetry is a sufficient but not a necessary condition for optical inactivity and nonresolvability; and (4) optical activity and resolvability are sufficient but not necessary conditions for molecular dissymmetry.

Employing the symbols A, $\overline{A}$, D, and $\overline{D}$ for optical activity and resolvability, optical inactivity and nonresolvability, molecular dissymmetry, and molecular symmetry, respectively, we may conveniently summarize these four conditions in diagrammatic form. The shaded areas A and $\overline{D}$ in FIGURE 3 lie entirely within circles D and $\overline{A}$ respectively, but there is an area of circle overlap where neither A nor $\overline{D}$ is found, and which is exemplified by compound *I*. The new criteria for optical activity and inactivity derive directly from the considerations in this section.

The terms "superimposable" and "nonsuperimposable" connote symmetry operations. For this reason, and because the lack of plane, point, or 4*n*-fold axis of symmetry no longer allows unequivocal predictions regarding optical activity and resolvability, we now advocate that adherence to geometric criteria be abandoned, and that their place be taken by the more "physical" statements (1) if a molecule and its mirror image are not (are) freely and spontaneously interconvertible, the aggregate is (is not) optically active, and (2) if the aggregate is (is not) optically active, the molecules and their mirror images are not (are) freely and spontaneously interconvertible.

Optical Activation of the 1,2,3,4-Dibenz-1,3-cycloöctadiene System

In connection with the previous problem, the question arises whether the individual molecules of *I* (FIGURE 2) are optically active or, whether, on a more operational level, an aggregate consisting of molecules all having the same given (frozen) conformation would exhibit optical activity. While *I* is totally dissymmetric, the projection of its structure is symmetrically constituted and the two halves possess asymmetric groupings of opposite configuration. In the general case of such compounds, for example, *meso*-compounds, the molecule is sometimes said to be inactive by "internal compensation," that is, each half of the molecule is said to have an exactly equal and opposite effect on the plane of polarized light, the total rotation thus becoming zero. This deeply embedded concept originated in the very earliest writings [1a,b,c] and not until recently was the idea challenged in a trenchant discussion by Noller,[13] who pointed out that optical activity is expected in dissymmetrically distorted *meso*-compounds. In rebuttal, Wright[14] took the position that a *meso*-compound may be regarded as made up of two nonsuperimposable halves, each rotating plane-polarized light in opposite directions to the same extent, regardless of the dissymmetry of the molecule as a whole. The crucial test was recognized to be the resolution of a compound whose dissymmetric molecules could be regarded as made up of two nonsuperimposable enantiomeric halves, for example, certain spiranes.[15] Claimed solutions to this problem suffered from the important detriment that the compounds investigated had molecules the halves of which were either superimposable[16] or nonenantiomeric;[17] the final test, until now, had therefore remained in abeyance.

In connection with our studies in the stereochemistry of the 1,2,3,4-dibenz-1,3-cycloöctadiene system, we recently resolved[18] the two 6,7-dicarboxylic acids.[19] If the biphenyl system is rigidly twisted, six stereomeric forms are possible in theory: (±)-*cis*, (±)-*trans A* and (±)-*trans B*; if, on the other hand, the biphenyl system readily passes through a planar (or equivalent) conformation, only three stereomeric forms will be isolable: *cis* and (±)-*trans*. Ultraviolet spectra[18,19,20] suggest that the biphenyl moiety deviates considerably from planarity. We found that one dicarboxylic acid racemized with a half life of 86 min. at 31.5°, while the other mutarotated with a half life of about 12 min. at the same temperature; consequently, the former is the *cis*-diastereomer and the latter one of the two possible *trans* forms. Enantiomerism in this system has thus been demonstrated. Racemization and mutarotation are schematized in FIGURE 4.

The projection of the *cis*-diastereomer is shown in FIGURE 5. Since the two asymmetric centers have opposite configurations, internal compensation should give an optically inactive molecule; this is clearly not the case. Obviously, at more elevated temperatures, the half life of

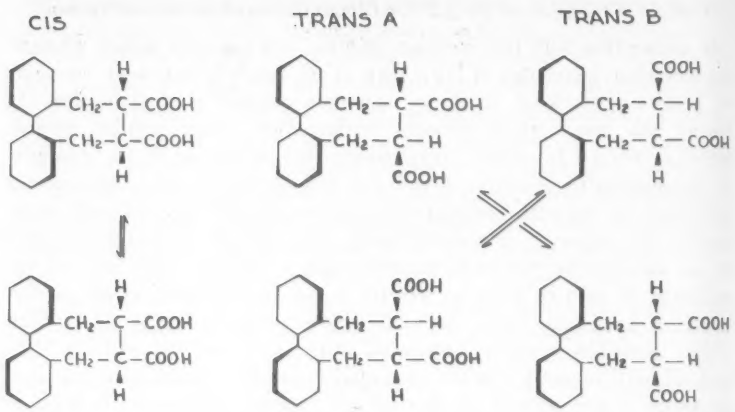

FIGURE 4.

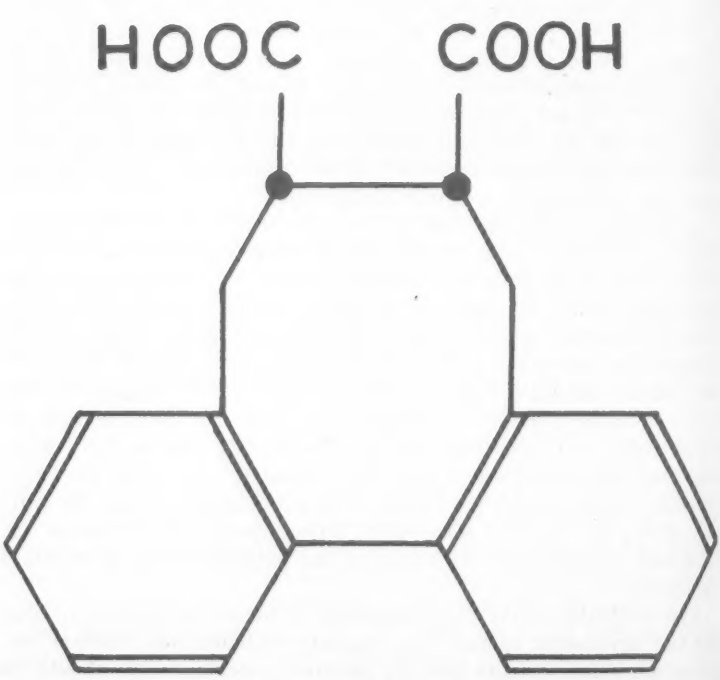

FIGURE 5.

optical activity would be sufficiently small to allow classification of this isomer as a classical *meso*-compound (or as a nonresolvable racemic mixture of the conformational type). The observed optical activation at room temperature, corresponding to the conjectured[13] optical activation of more conventional *meso*-compounds at extremely low temperatures, provides the first formal experimental refutation of "internal compensation." More particularly, we can now state that individual molecules of *I* (FIGURE 2) are also expected to be optically active.

It is to be noted that the presence of a biphenyl system here is relatively trivial; our results suggest that *cis*-1,3-cyclooctadiene-6,7-dicarboxylic acid, for example, should also be resolvable at room temperature.

Methods of Configurational Intercorrelation in the Biphenyl Series

The direct chemical intercorrelation of configurations in the biphenyl series is uncomplicated by the problem of Walden inversion: retention of configuration and racemization are the only alternatives. Thus, in a chain of chemical interconversions affecting the blocking substituents, if optical activity is retained in the product, configurations of starting material and product have been correlated. An example is the chemical correlation of (–)-6,6′-dinitro-, (–)-6,6′-dichloro- and (+)-6,6′-dimethyl-2,2′-diphenic acids with (–)-6,6′-diamino-2,2′-dimethylbiphenyl,[21] summarized in FIGURE 6. In the illustrated scheme, as well as in others, direct chemical correlations are rather complex and may present near-insurmountable difficulties in synthesis. Therefore we investigated the possibility of employing an indirect method of correlation. No indirect methods have thus far been reported for other than centrally asymmetric compounds.

An examination of the literature reveals that in the great majority of

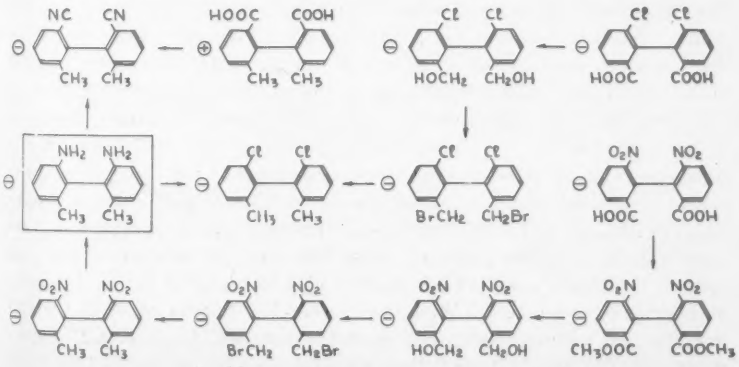

FIGURE 6.

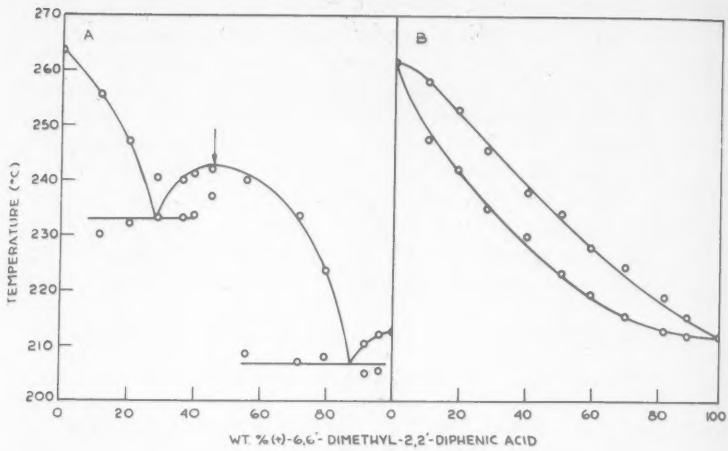

FIGURE 7.

cases the melting point of hindered (±)-biphenyls is considerably higher than that of the (+)- and (–)- forms. Clearly, racemate formation is the general case in this series. This observation encouraged us to examine the applicability of the method of thermal analysis to the biphenyl series. The method referred to has been extensively employed in the series of centrally asymmetric compounds, principally by Fredga and his school,[22] and it has recently served in our laboratory in the elucidation of the configuration of hydratropic acid[23] and of α-lipoic acid.[24]

We found[25] that the three configurationally related diacids shown in FIGURE 6 form solid solutions, whereas the diacids of opposite configuration form 1:1 quasi-racemates, as illustrated in FIGURE 7 for the pairs (+)-6,6′-dimethyl-2,2′-diphenic acid vs. (+)- and (–)-6,6′-dichloro-2,2′-diphenic acids (curves *A* and *B* respectively). The conclusions derived from this phase behavior are in complete agreement with the correlations that had independently been established via direct chemical paths (FIGURE 6); it is particularly gratifying that the observed differences in phase behavior are the most clear-cut of the three significant types.[23] Thermal analysis of mixtures of 6,6′-dichloro-2,2′-bis(hydroxymethyl)biphenyl and 6,6′-dimethyl-2,2′-bis(hydroxymethyl)biphenyl also gave significant differences in phase behavior, demonstrating that the method of thermal analysis can be extended to biphenyl diols. However, an attempt to correlate 2,2′-bis(hydroxymethyl)-1,1′-binaphthyl by thermal analysis of mixtures with the enantiomeric 6,6′-dimethyl-2,2′-bis(hydroxymethyl)biphenyls failed, thus showing limitations imposed by overall structural requirements.

It has thus been demonstrated, for the first time, that noncentrally asymmetric compounds may be configurationally intercorrelated by other than direct chemical paths; specifically, Fredga's method has been extended to include conformational enantiomers of the biphenyl type. We expect that application of this technique will aid considerably in, and render less time-consuming, problems of biphenyl configuration.

In the hope of applying the optical displacement principle[26] to the solution of problems in this area, we examined[25] the rotations in different solvents of 2,2′-dicarboxy-, 2,2′-dicarbethoxy, 2,2′-bis(hydroxymethyl)-, 2,2′-bis(bromomethyl)- and 2,2′-dimethyl-derivatives of 6,6′-dinitrobiphenyl, 6,6′-dichlorobiphenyl, 6,6′-dimethylbiphenyl and 1,1′-binaphthyl. No definite conclusions could be reached from this examination: the trends in rotation for analogous derivatives were too irregular. It would appear at this time that this method is not suitable for configurational correlations in the biphenyl series.

It should be noted, in conclusion, that we have been referring to the configuration of biphenyls when, properly speaking, the mirror-image forms are enantiomeric *conformations*. In cases like this, where enantiomerism is of the conformational type, the term "configuration" is not being used in its more classical sense; nevertheless, I feel that "configuration," as being used in this and the following section, when referring to the systems of conformational enantiomers, cannot have any misleading connotations and can serve as usefully in the biphenyl system as in the series of centrally asymmetric compounds.

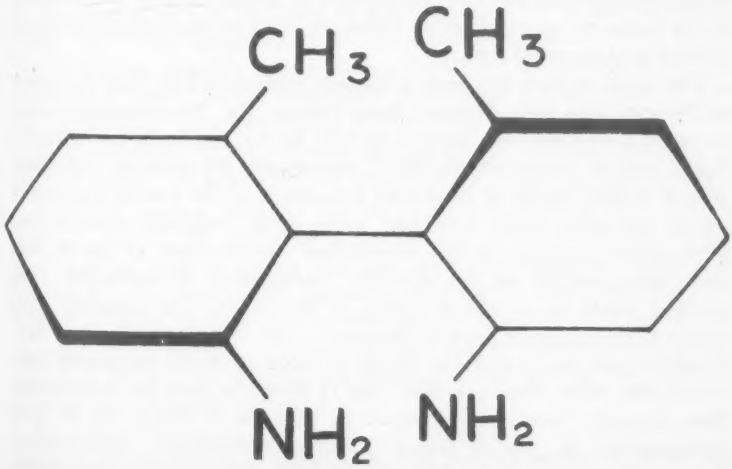

FIGURE 8.

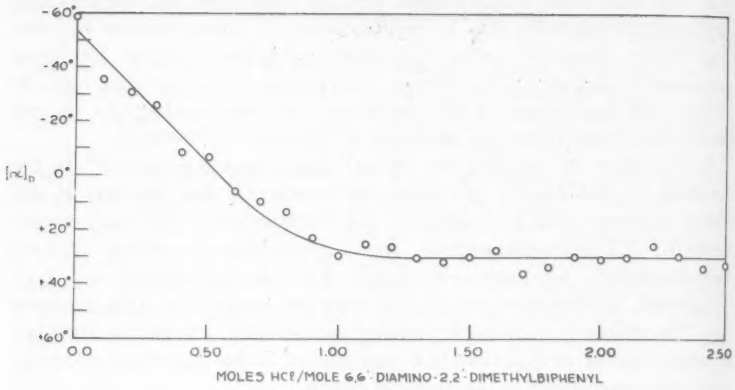

FIGURE 9.

The Absolute Configuration of Biphenyls

The problem of the absolute configuration of biphenyls is a major one in stereochemistry. Using Cahn-Ingold-Prelog nomenclature,[27] the problem may be stated in this typical fashion: does (+)-6,6′-dinitro-2,2′-diphenic acid have the *R* or the *S* configuration?

In general, three methods are available for establishing the absolute configuration of an optically active compound: X-ray diffraction, theoretical calculation, and chemical correlation with a compound whose absolute configuration has been established by one of the first two methods. In the series of optically active biphenyls all three approaches are being studied at the present time.

The X-ray method has been admirably discussed[28] by Ray Pepinsky of Pennsylvania State College, State College, Pa. The anomalous scattering of X rays has been used to identify the hand of NaRb ((+)-tartrate · H_2O[29] and of (−)-isoleucine · HBr;[30] accordingly the absolute configuration of a vast number of correlated compounds of the central asymmetry class, including sugars, alkaloids, amino acids, terpenes, steroids, and other natural products, is now established. Nevertheless, as yet no work has been reported on the absolute configuration of biphenyls. The problem could be solved in either of two ways. The detailed X-ray analysis of a salt of (+)-6,6′-diamino-2,2′-dimethylbiphenyl with, say, (+)-malic acid would give the spatial orientation of one component *relative* to the other; since (+)-malic acid is known to have the *R*-configuration, it would therefore in principle be possible to assign the *R*- or *S*-configuration to (+)-6,6′-diamino-2,2′-dimethylbiphenyl. Alternatively, the hydrobromide or hydriodide of (+)-6,6′-diamino-2,2′-dimethylbiphenyl might be examined directly, using the anomalous X-ray scattering tech-

nique. Approaches similar to the ones described are being actively investigated.[31]

The calculation of the absolute configuration of (+)-6,6′-diamino-2,2′-dimethylbiphenyl by the theory of coupled electronic oscillators, recently reviewed by Kuhn,[32] has led to the assignment[33] of the *S*-configuration (FIGURE 8). We have found,[34] however, that the sign of rotation of this compound is *p*H-dependent (FIGURE 9), so that the earlier conclusions[33] are rendered ambiguous. According to Kirkwood's polarizability theory of optical activity,[35,36] a change in sign of rotation is associated with a change in the quadrant of the interplanar angle θ[37] (FIGURE 10). The change of sign of rotation with *p*H may then be accounted for by interactions in the protonated form that lead to a change in quadrant of θ. Assuming on the basis of dipole moment measurements[38] that $0° < \theta < 90°$ for 6,6′-diamino-2,2′-dimethylbiphenyl in benzene solution, the dextrorotatory enantiomer accordingly (FIGURE 10) has the *S*-configuration.[37]

If we accept the results of calculations and, when they become available, of X-ray analysis, we shall be in the position to assign absolute configurations to the many compounds related to 6,6′-diamino-2,2′-dimethylbiphenyl; this includes all of the compounds shown in FIGURE 6. There is, however, a third approach that consists of *chemically* relating the configuration of a biphenyl to that of a centrally asymmetric compound of known configuration. It is clear that, whatever the method chosen, it would be necessary, at one stage in the correlation, either to create dissymmetry of the hindered biphenyl type from dissymmetry of the asymmetric carbon type, or vice versa. Several examples of this type of transformation can be found in the literature.[39,40] In one particular case, that of the thebaine-phenyldihydrothebaine interconversion, analysis of the two possible diastereomeric transition states has in fact recently been used[41] in the assignment of absolute configurations to certain substituted biphenyls through a fairly complex series of correlations to glyceraldehyde via the thebaine alkaloid group. Thus far, however, no *general* method for achieving the desired correlation has been reported.

A simple working principle has led us to a solution of this problem. The principle is the following. If the transformation occurs in a single step and in such a manner that the step constitutes an asymmetric synthesis of a structurally symmetrical biphenyl, then, providing the transition state is amenable to detailed and convincing geometric description, a correlation of the desired type can be arrived at through application of the well-established principles that govern the paths of asymmetric syntheses in general.

We have chosen as the basis for our asymmetric synthesis the Meerwein-Ponndorf-Verley equilibrium, the stereochemistry of which has been thoroughly worked out, principally by Doering.[42] In this reaction,

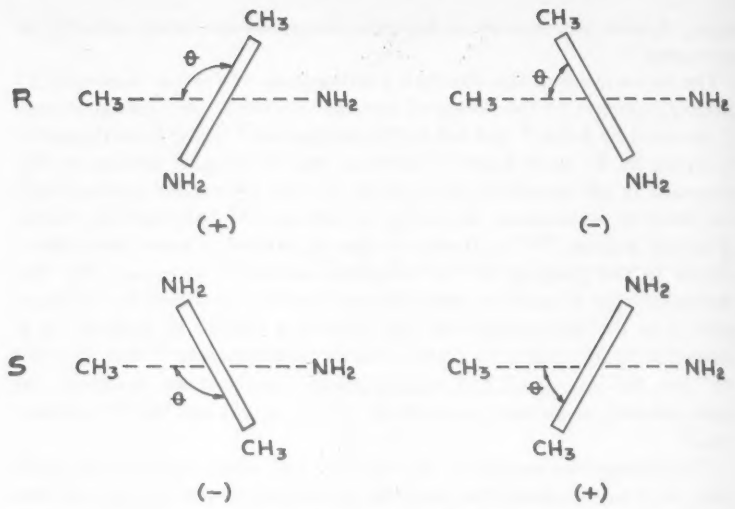

FIGURE 10.

diastereomeric transition states *A* and *B* (FIGURE 11) have different free energies; specifically, if $R_1 > R_2$ and $R_3 > R_4$ in bulk size, transition state *A* will be preferred over *B* since nonbonded interactions of juxtaposed groups in *A* (R_1-R_4 and R_2-R_3) will be less than those in *B*. In the resulting asymmetric synthesis, the enantiomer of R_1R_2CHOH which is produced in excess (that is, faster, via *A*) can be related configurationally to reducing alcohol R_3R_4CHOH.

In the Meerwein-Ponndorf-Verley reduction, an asymmetric center is created in a nonracemic substance: R_1R_2CHOH is formed from R_1R_2CO.

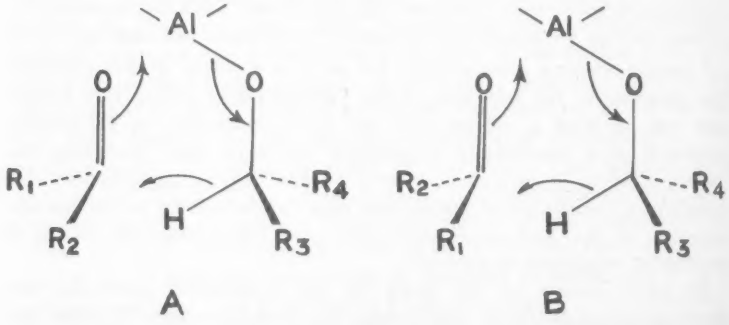

FIGURE 11.

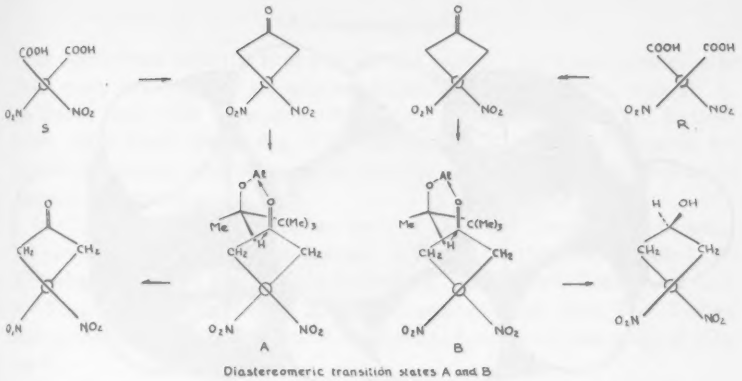

FIGURE 12.

In the biphenylic system that we have devised, 4′,1″-di-substituted 1,2,3,4-dibenz-1,3-cycloheptadiene-6-one (DBCH-6-one), we begin with a racemic mixture of *S*- and *R*- ketone. Reduction to the 6-ol can give only one racemic mixture (no diastereomer), since the alcohol produced from, for example, *S*-DBCH-6-one, must be the *S*-DBCH-6-ol.

In the particular compound that we have studied, 4′,1″-dinitro-DBCH-6-one, reduction with aluminum (+)-pinacoloxide will proceed via two diastereomeric transition states *A* and *B*, as schematically indicated in FIGURE 12. Complete reduction of racemic 6-one must give racemic 6-ol,, as explained above. In fact,[44] reduction with a large excess of aluminum (+)-pinacoloxide at 100° for 36 hr. gives pure, optically inactive, 6-ol. Suppose, however, that the reduction is not allowed to go to completion.

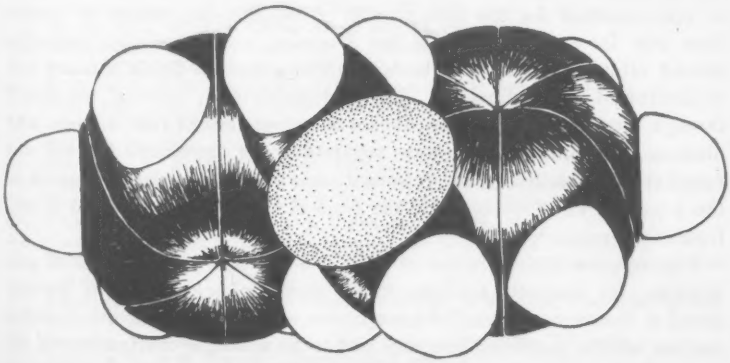

FIGURE 13.

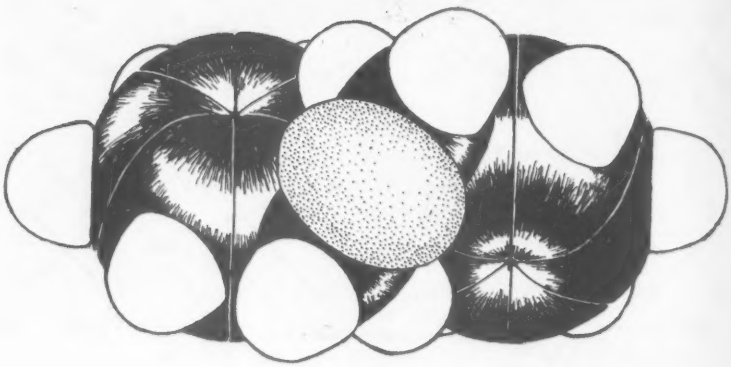

FIGURE 14.

It is known that (+)-pinacolyl alcohol has the *S*-configuration,[43] and thus hydride transfer to *either* side of the carbonyl group of *S*-DBCH-6-one would involve very considerable steric interference between the large t-butyl group and the "jutting" phenyl; FIGURE 13 is a top view of *S*-DBCH-6-one with the 4′,1″-positions shown unsubstituted for sake of clarity (the nature of the blocking substituents does not enter into the argument; their function is to ensure molecular rigidity and optical stability). The corresponding transition state is *A* (FIGURE 12). On the other hand, hydride transfer to *either* side of the carbonyl group of *R*-DBCH-6-one (FIGURE 14) would involve very little nonbonded interaction; only the methyl group would interfere with the jutting phenyl. The corresponding transition state is *B* (FIGURE 12). Hence, the specific rate constant for the reduction of *R*-DBCH-6-one would be greater than that for the reduction of the *S*-isomer, and *incomplete* reduction should afford a mixture of alcohol and ketone with *S*-DBCH-6-one and *R*-DBCH-6-ol predominating. The ketone-alcohol mixture obtained[44] through incomplete reduction (63° for 7 hr.) of the *RS*-DBCH-6-one with aluminum (+)-pinacoloxide was separated: the unreduced ketone was found to be enriched in the (+)-enantiomer and the produced alcohol in the (–)-form. The (+)-6-one and the (–)-6-ol thus have the *S*- and *R*-configurations respectively.

The relative configuration of the (+)-6-one and closely related substances, for example, 6,6′-dinitro-2,2′-diphenic acid, is being investigated at the present time.[45] We anticipate that the work described in this section and the preceding one will lead to the absolute configurational assignment of the large class of common, hindered biphenyls, including the first member of the series.[2]

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SECTION OF BIOLOGY

A COMPARATIVE STUDY OF PHOTORECEPTORS*

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A comparative study of photoreceptor structures and their associated pigments is under investigation in our laboratory in order to learn something of the "light-trapping" mechanisms in living systems. As a part of this study of plant and animal photoreceptors we are investigating: (1) the structure of the photoreceptors by electron microscopy and, from analytical methods, the molecular size of the pigment macromolecule; (2) the spectral sensitivity or action spectra of the organism; and (3) the photochemistry of the pigment complexes.

Structure

By electron microscopy we have studied the photoreceptors, chloroplasts of algae and higher plants, the eye-spots of *Euglena*, the retinal rods of cattle and the frog, and the ommatidia of the insect eye of *Drosophila melanogaster*.

The photoreceptors were fixed in 1 per cent buffered osmium tetroxide, embedded in *n*-butyl methacrylate and polymerized by heat; with a Porter-Blum microtome, 300 to 500 Å. sections of the specimens were cut with glass knives from the polymerized blocks.

For the electron microscopy of chloroplasts and a schematic molecular structure one may refer to Wolken,[1,3] Wolken and Palade,[12,13] Wolken and Schwertz,[14,15] and to recent reviews on the structure of chloroplasts by Thomas[16] and Mühlethaler.[17]

All of the animal photoreceptors studied – frog, cattle, and insect – appear in the electron micrographs as stacked plates and discs or as packed rods with dense layers 100 to 200 Å. and less dense interspaces 200 to 500 Å. (Wolken[1,3], Wolken, Mellon, and Contis,[2] and Wolken, Capenos, and Turano[4]). The dimensions of some of these photoreceptors, as measured from the electron micrographs and the pigment concentration, are listed in TABLE 1. A schematic molecular model for the retinal rod is illustrated in FIGURE 1. By similar techniques for electron microscopy Sjöstrand,[5,6] DeRobertis,[7] and Fernández-Morán[8] have studied the retinal rods of the guinea pig and rabbit, the rods and cones of the perch, and the

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TABLE 1

PHOTORECEPTOR

Structural Data from Electron Microscopy

Photoreceptor	D, *photoreceptor diameter* μ	T, *thickness of dense layers* Å.	n, *number dense layers per photoreceptor*	N, *number pigment molecules per photoreceptor*	M, *calculated molecular weight pigment complex*
Chloroplast *Euglena*	8.3	242	21	1.0×10^9	21,000
Frog retinal rod *Rana pipiens*	5.0	150	1000	3.8×10^9	60,000
Cattle retinal rod	1.0	200	180	4.2×10^6 *	40,000
Rhabdomere *Drosophila melanogaster*	1.2	120	1380	1.0×10^9 †	14,000

* Value of Hubbard.[20]

† Calculated value from geometry.[1]

ommatidia of the house fly. There appears to be a general lamellar fine-structure common to all photoreceptors so far studied by electron microscopy. In addition it has been shown that insects (honey bee and *Drosophila*) exhibit orientation relative to the direction of vibration of polarized light (von Frisch,[9] and Stephens *et al.*[10]). The sensitivity to plane-polarized light suggests an analyzer within the eye. Investigations on the electric potential of the compound eye exposed to polarized light indicate that neither the whole eye nor a single ommatidium acts as the analyzer (Autrum and Stumpf[11]). In cross section a *Drosophila* ommatidium shows 7 retinula cells and its 7 rhabdomeres radially arranged. The rhabdomeres average 1.2 μ in diameter and 60 μ in length (TABLE 1). The rhabdomere, as we have described it, has parallel rather than radial symmetry in cross section (Wolken, Capenos, and Turano[4]). The radial arrangement of the rhabdomeres within the ommatidium of radially unsymmetrical rhabdomeres would indicate a relationship to the analysis of polarized light in the insect eyes. The *Euglena* "eye," the light receptor for phototaxis, appears in the electron microscope as 40 to 50 tightly packed granules 0.2 μ in diameter. This hexagonal packing is indicative of rods, but no "fine" structure can be observed at this level of resolution (Wolken).[3]

Calculation of molecular weight from structure. The photoreceptor lamellar structure, as we visualize it, consists of alternate layers of lipoprotein* and aqueous proteins as shown in FIGURE 1. According to the schematic model, there are monomolecular layers of pigments at the interfaces between these layers, with each pigment molecule bound to a

*Lipoprotein is used here in preference to "lipid layer" since it includes the pigment, lipids, and the macromolecules. There are no chemical analyses of these layers at present, but the dense layers are so designated because of the affinity of osmium tetroxide for lipids, which increases the electron density.

single lipoprotein macromolecule. In this view, the dense layer containing the lipids and lipoproteins consists of a double layer of lipoprotein macromolecules with the low molecular weight lipids occupying the interstitial spaces. This arrangement is shown in the enlarged section of FIGURE 1. The maximum cross-sectional area A, associated with each macromolecule, and therefore with each pigment molecule, is

$$A = \frac{\pi D^2}{4P} \tag{1}$$

where D is the diameter of the photoreceptor and P is the number of pigment molecules in a single monomolecular layer. The maximum possible volume V, associated with a macromolecule, is then

$$V = \frac{\pi D^2 T}{8P} \tag{2}$$

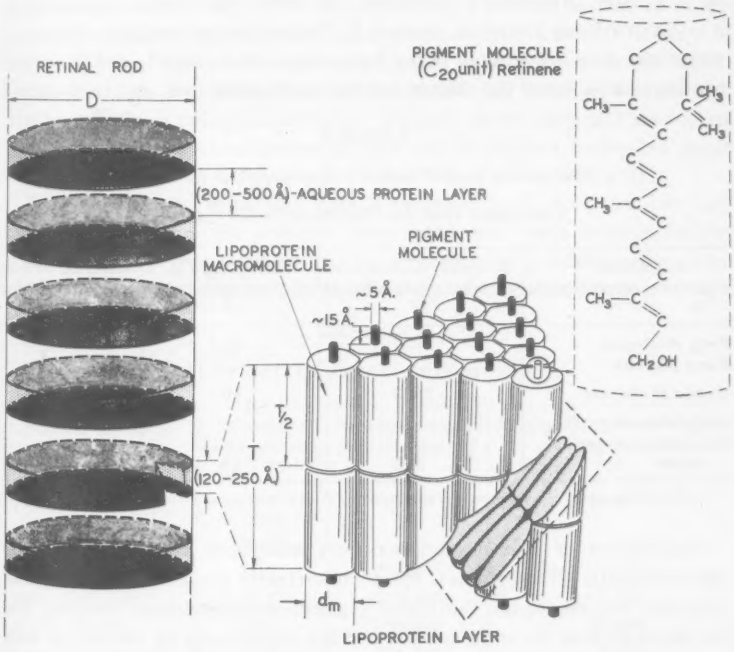

FIGURE 1. Schematic molecular model for a retinal rod, indicating double layers of macromolecules and their dimensions, and showing one pigment molecule (C_{20} unit) per macromolecule.

where T is the average thickness of the lipid-lipoprotein dense layers. The maximum pigment-macromolecule molecular weight, M, is therefore

$$M = \frac{\pi D^2 T s L}{8P} \tag{3}$$

where s is the protein density and L is Avogadro's number. If N is the pigment concentration expressed in molecules per photoreceptor and n is the number of dense layers per photoreceptor, then

$$P = \frac{N}{2n} \tag{4}$$

EQUATION 3 may therefore be written in a form containing only the experimental observables

$$M = \frac{\pi D^2 T s L n}{4N} \tag{5}$$

To calculate the molecular weight, s is 1.3 (density of a protein) and L is 6×10^{23} (Avogadro's number). The other quantities appearing in EQUATION 5 are listed in TABLE 1. The molecular weights calculated with these data are entered in the last column of TABLE 1, and the cross-sectional area A and the diameter of the macromolecules, d_m, in TABLE 2.

TABLE 2

DIMENSIONS OF PIGMENT MACROMOLECULES

Calculated from the Photoreceptor Geometry

Retinal pigment-macromolecule	A, *cross-section area of macromolecules in* $\AA^2$	*Diameter,* d_m, *of macromolecules* $\AA$	*Length,* T/2 *of macromolecules* $\AA$
Frog rhodopsin *Rana pipiens*	2620	51	100
Cattle rhodopsin	2500	50	100
rhabdomere-complex *Drosophila melanogaster*	312	18	60

For chloroplastin macromolecule see Wolken,[1,3] and Wolken and Schwertz.[14]

Calculation of pigment-complex from analytical data. Chloroplastin and rhodopsin. Chloroplastin, the photosynthetic pigment-macromolecular complex, and rhodopsin, the visual pigment-macromolecular complex, can be prepared from the chloroplasts and the retinal rods by extraction with digitonin (Wolken,[2] and Collins, Love, and Morton[18]). It is difficult to measure the purity of these complexes, but rhodopsin can be estimated by the criteria of Wald,[19] using the ratio of its optical density in $m\mu$ $K\frac{400}{500}$,

the minimum to that of the maximum. The purer the extract, the lower the ratio. The sedimentation of these complexes for algal chloroplastin and frog rhodopsin were studied in the analytical ultracentrifuge. From the sedimentation constant (S_{20}) the molecular weight of the complex can be calculated from the Svedburg equation

$$M = \frac{RTS_{20}}{D_{20}(1-p\bar{V}_{20})}$$

where R is the gas constant, T the absolute temperature, S_{20} the experimentally determined sedimentation, D_{20} the diffusion constant, p the density, and $\bar{V}_{20}$ the partial specific volume (TABLE 3).

From analyses, the dry weight of algal chloroplastin averaged 28.63 mg./ml., of which 6.06×10^{-5} mol/l. was chlorophyll and 0.36 mg./ml. was nitrogen; the dry weight of rhodopsin averaged 20 mg./ml., of which 2.2×10^{-6} mol/l. was pigment and .026 mg./ml. was nitrogen (Wolken).[1] With this information we can evaluate a minimum molecular weight. For frog rhodospin, from the ultracentrifuge data, we have calculated the average molecular weight to be 67,000 (TABLE 3). The molecular weight calculated from the geometrical considerations above is 60,000 (TABLE 1). These independent methods (TABLES 1 and 3) are in reasonable agreement. Our data for cattle rhodopsin is 40,000 and is in agreement with Hubbard.[20] From calculations of the maximum cross-sectional area occupied by the pigment-macromolecule, the retinal pigment molecules would be loosely packed at the interfaces in the retinal rod (TABLE 2).

Further, from the analytical data it is possible to show that one pigment molecule is most probably associated with each macromolecule. This is done by demonstrating that the experimentally determined pigment concentration p is substantially the same as p' calculated from $p' = \frac{w}{M'}$,

TABLE 3

ANALYTICAL ULTRACENTRIFUGE DATA

Pigment complex in digitonin	*Average sedimentation* $S_{20} \times 10^{13}$	*Average complex micelle weight* M′	*Average molecular weight pigment complex* M
Digitonin[1,33,20]	7.1 5.88 6.35	155,000	155,000
Euglena chloroplastin[1]	13.5	290,000	40,000
Cattle rhodopsin[20]	9.77	275,000	40,000
Frog rhodopsin[1]	12.1	295,000	67,000
Drosophila extract[3]	9.3	225,000	4,000

M' is calculated from M using the dry weights and per cent nitrogen used by Hubbard.[20] Smith and Pickels[34] have shown that digitonin forms micelles of minimal molecular weight of 75,000. Hubbard[20] indicates three such micellar units associated with rhodopsin.

w, weight of dried residue over M', ultracentrifuge weight of micelle complex (Wolken and Schwertz,[15] Wolken,[1] and Hubbard[20]). The possibility that the macromolecule may span the width of the dense layer and that there may be two pigment molecules per macromolecule cannot be excluded. All experimental evidence to date indicates a 1:1 ratio. The structure of the retinal rod from electron microscopy and analytical data is schematically represented in FIGURE 1.

Little is known chemically of the proteins "plastin" or "opsin" and of how the pigments (chlorophyll, retinene, or other carotenoids) are

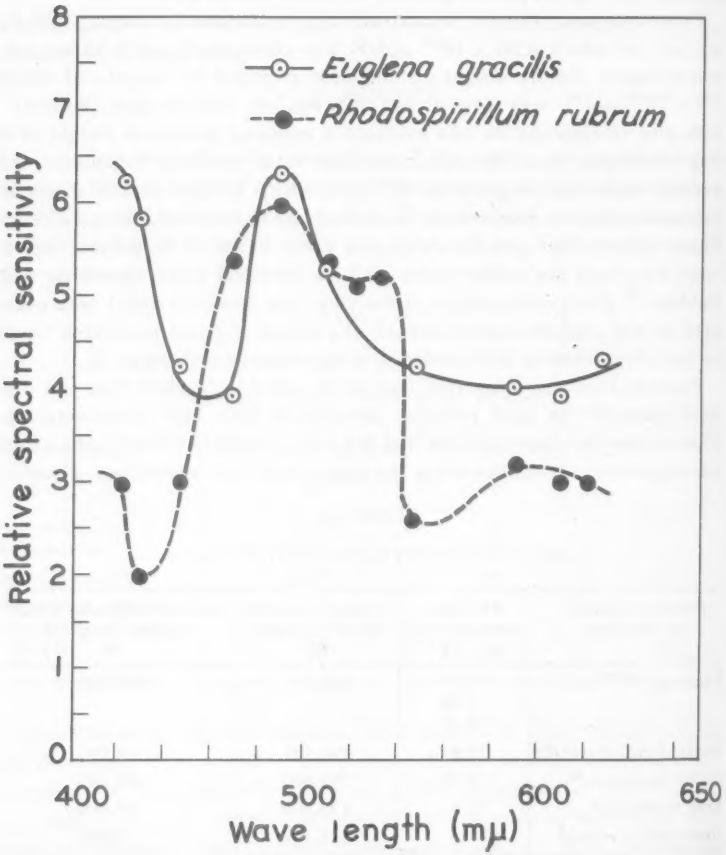

FIGURE 2. Action spectra for *Euglena gracilis* —⊙—, and *Rhodospirillum rubrum* - -●- -.

linked to the macromolecules at present. The molecular weights calculated for the photosynthetic plastin or visual opsin may be indicative of species variation of the macromolecule.

Spectral Sensitivity

We have studied the action spectra of an algal flagellate, *Euglena gracilis;* a photosynthetic bacterium, *Rhodospirillum rubrum;* a photosensitive fungus, *Aspergillus giganteus;* and an insect, *Drosophila melanogaster.* Comparative spectral sensitivity curves are reproduced in FIGURES 2 and 3.

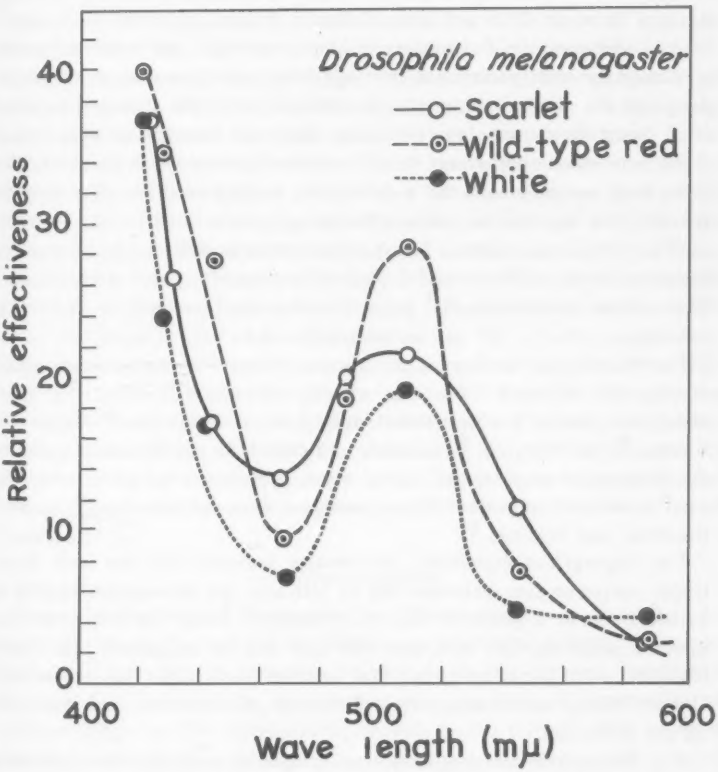

FIGURE 3. Effectiveness spectrum or action spectrum for three *Drosophila melanogaster* eye mutants, scarlet —O—, wild-type red - -⊙- -, and white ---●--- (against a blue standard, 421 mμ).

Euglena gracilis possesses two photoreceptors, the eye spot for light detection and the chloroplast for photosynthesis. Phototaxis is associated with the eye-spot pigments, and our action spectra indicate absorption peaks at 420 and 495 mμ in agreement with Bünning.[21] These absorption peaks are supposedly those of the red carotenoid, astaxanthin. Although red variants of *Euglena* have been found to contain astaxanthin, and although our action spectra are certainly suggestive of this pigment, no one has isolated or identified the pigment in the eye spot of *Euglena*. From the experimental data for the rate of movement and from knowledge of the maximum absorption peak (465 mμ), the light intensity, and the cross section of the eye-spot granules, we have calculated that *Euglena* can detect a minimum of 7 photons. This corresponds to a quantum efficiency of about 14.3 per cent (Wolken,[3] Wolken and Shin).[22] Manten[23] studied phototaxis in *Tolypothrix*, a blue-green alga, and indicated points of similarity with phototaxis in flagellates and green algae. When he compared the action spectrum of phototropism with the absorption spectra of 2 isolated carotenoids, he found that the absorption spectrum of β-carotene was in agreement with the action spectrum and concluded that β-carotene probably acts as a sensitizer in phototropism. For *Euglena gracilis*, the spectral response absorption peak related to rate of movement is at 465 mμ, whereas for phototaxis it is at 495 mμ; taken together, these could be indicative of 2 pigments, β-carotene and astaxanthin.[22] The number of molecules of pigment within the eye spot of *Euglena* is calculated to be 1×10^6 per monolayer.

For *Rhodospirillum rubrum*, the spectral sensitivity curve shows peaks at 420, 465, 490, and 530 mμ for a 7-day-old culture (FIGURE 2). These absorption peaks are in general agreement with Manten,[23] Milatz and Manten,[24] and Clayton,[25] and they indicate that spirilloxanthin may be the phototactic pigment, but that for young cultures the phototactic pigment associated with the 530 mμ peak is not as yet identified (Van Niel, Goodwin, and Sissins).[26]

For *Aspergillus giganteus*, our results indicate that the best phototropic response lies between 466 to 503 mμ; the absorption spectra in pyridine shows a peak at 420 mμ. Gardner[27] found for the absorption spectra peaks at 420, 450, and 475 mμ, and he suggested that it was identical with β-carotene, but that another phototactic absorption peak lies at 380 mμ and is suggestive of another photosensitive substance not as yet identified.

For *Drosophila melanogaster*, the compound eyes possess screening and reflecting pigments that may not be directly concerned with vision, but serve only to regulate the amount of light reaching the retinula cells. The phototactic response curves obtained by Fingerman[28] indicate that the basic curve for *Drosophila* phototaxis is that of the white-eyed fly

and that the other response curves differ from that of the white fly only because of the screening effects of their eye-color pigments. As a result of Fingerman's finding that at no wave length did one eye-color group respond in the same way to varied light intensity, we have measured the response to light intensity and have found that it yields similar families of curves. These permit the conversion of the response data to determine an action spectrum for the photoreceptor substance. In determining the action spectrum the flies were given a choice between two wave lengths, one of which was kept constant and the other varied. The flies were dark-adapted prior to the determinations and between measurements in order to insure that the pigment granules had withdrawn from around the ommatidia. Exposure to light was for short periods of time, less than five minutes. In this way, the response would be basically that of the "visual" pigment. We have found that for the three eye mutants of *Drosophila* – scarlet, wild-type red, and white-eyed – the action or effectiveness spectra all show a maximum at 508 mμ, which may indicate that the absorbing pigment in these insects is similar to the visual complexes found in the vertebrate photoreceptors (FIGURE 3). We have been unable to extract from the eyes of *Drosophila* a pigment that has an absorption peak around 508 mμ. The extractable pigments from the scarlet and wild-type red flies in digitonin indicate absorption peaks in the ultraviolet at 270 mμ and a plateau near 315 mμ and in the visible at 480 mμ and a minimum near 550 mμ (Wolken, Mellon, and Contis).[2] No absorption in the visible range was found for the white-eye extracts.

The spectral sensitivity for a variety of organisms appears essentially similar to those of the animal photoreceptors and shows an absorption in the neighborhood of 500 mμ, that of the carotenoids. The nature of the end process, however, is different. The information on spectral response is helpful, but some systematic study of the pigments is required for the photoreceptor structures in a great variety of organisms (Wald[29] and Crescitelli[30]).

Photochemistry

Since the function of photoreceptors (photosynthetic or visual) is to trap light energy for transfer to chemical or electrical energy, and since there is a similarity in structure as well as in the pigment complex in digitonin (as indicated by the electron micrographs and the analytical ultracentrifuge for the chloroplasts, as well as the retinal rods), we were curious to see whether chloroplastin is similar to rhodopsin with respect to light and heat activation. Rhodopsin has been shown to bleach by both light and heat. This was studied by St. George[31] for frog and cattle rhodopsin. Lythgoe and Quilliam[32] have found that rhodopsin (*p*H 6.2) bleaches rapidly in the dark at temperatures of 50° C. and above, and

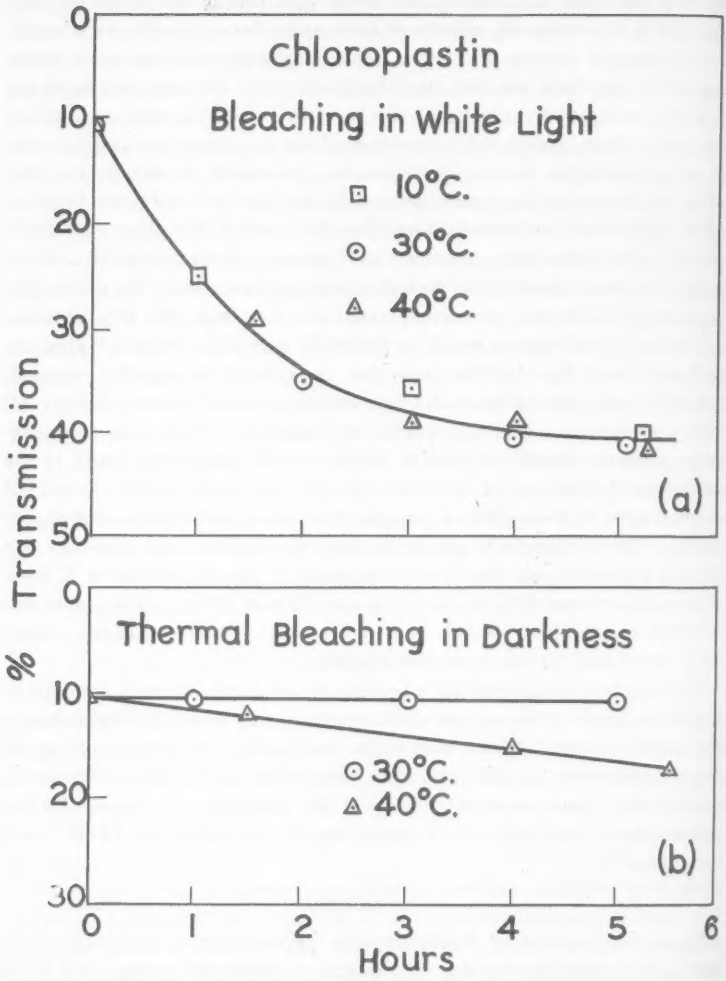

FIGURE 4. Bleaching algal chloroplastin (in 1.8 per cent digitonin) for different temperatures: (a) in white light, and (b) in darkness.

they have calculated an experimental activation energy of 44 kg. cal./mol for bleaching (*p*H 6.2). St. George has shown that the bleaching rate of rhodopsin in light becomes temperature-dependent at about 590 mμ. This is the longest wave length at which bleaching occurs without the addition

of a significant amount of thermal energy. An activation energy of 48.5 kg. cal./mol for bleaching in light was obtained.

Bleaching of algal chloroplastin (*p*H 7.2) in light takes place at a rate that is independent of temperature (FIGURE 4a). In darkness no measurable bleaching occurs until the temperature is raised above 30° C. (FIGURE 4b). The temperature coefficient, the ratio of the slopes of the bleaching rate in the temperature, ranges from 10° to 40° C. is 1. The experimental activation energy for thermal bleaching in darkness can be calculated from the Arrhenius equation. The experimental activation energy calculated for thermal bleaching is 48.5 kg. cal./mol. Chloroplastin was also bleached at various wave lengths for the same temperature range. It was observed that the rates of bleaching below 560 mμ are the same (Q_{20} is nearly 1); however, at longer wave lengths the bleaching rate increases. Again using the Arrhenius equation, an experimental activation can be calculated for light bleaching. Therefore the bleaching of chloroplastin is possible, not only by light energy, but also by heat alone or by a combination of both (TABLE 4).

TABLE 4

ACTIVATION ENERGY OF BLEACHING

	Comparative rate of bleaching at all temperatures in white light	*Calculated experimental activation energy for thermal bleaching in darkness*	*Experimental wave length at which temperature dependence of bleaching begins*	*Calculated experimental activation energy for light bleaching*
Chloroplastin *Euglena*	1	48.2 kg. cal./mol	560 mμ	48.3 kg. cal./mol
Rhodopsin[31] frog, cattle	1	44.0 kg. cal./mol[32]	590 mμ	48.5 kg. cal./mol

St. George,[31] Lythgoe and Quilliam.[32]

The combined effects of light and heat as observed in the bleaching at any temperature in white light approach unity for both rhodopsin and chloroplastin. When the quantum energy decreases below 48.5 kg. cal./mol, the energy of the quantum at 590 mμ, the temperature coefficient for rhodopsin increases. Similarly, when the quantum energy decreases below 48.3 kg. cal./mol, the effective quantum energy at 560 mμ, the temperature coefficient for chloroplastin increases. At wave lengths greater than 560 mμ, the greater part of the total energy used in bleaching of chloroplastin is due to heat; the rest is due to light energy, but the total energy required for bleaching remains approximately the same. For wave lengths smaller than 560 mμ, the light energy becomes greater as the wave length decreases, and the total energy required for bleaching is supplied by light energy. We are not implying that photosynthesis and vision are the same; we merely call attention to a comparative similarity

between the minimum calculated experimental activation energies for bleaching of algal chloroplastin and those of frog and cattle rhodopsin, as given in TABLE 4.

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SECTION OF MATHEMATICS AND ENGINEERING

PROBLEMS OF STRUCTURAL DESIGN FOR ELEVATED TEMPERATURES*

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The necessity of designing structures for operation at elevated temperatures during various times and cycles of operation, such as aircraft at supersonic speeds and nuclear reactors, has created for the structural designer problems that cannot be solved by conventional methods of structural analysis and design, but require the development of new concepts of method and design.

The principal problems arising in the analysis and design of high-temperature structures are (1) the necessity to consider the operational life as a primary design characteristic and to distinguish between design conditions of various duration; (2) the emergence of the thermal stress problem as a significant or even critical design problem; (3) the necessity to consider the deviation from elasticity of the mechanical response of structural materials, requiring the introduction of methods of inelastic stress analysis; the strong variation with temperature of certain parameters of this analysis, such as the creep- or relaxation coefficients and the thermal conductivity; (5) the appearance of complex interaction phenomena between load effects and temperature effects arising from problems Nos. 2 to 4; and (6) the selection of structural materials for various types of high temperature performance on the basis of certain combined mechanical-thermal characteristics.

Design Significance of Operational Life

The importance of the specification of the total operational life, as well as of the various design conditions with their respective durations, is the result of the time-dependence of the deformation and of the fracture strength of all structural materials at elevated temperatures. This dual time-dependence, designated as "creep" and "creep rupture," introduces the necessity to distinguish between structures designed for various orders of magnitude of operational life, ranging from guided missiles that might be designed for less than one-half hour of service to permanent power plants designed for 100,000 hrs. of operation or more, as well as to distinguish between the two design criteria of (1) permissible total permanent deformation that might be attained at the end of the service life

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(creep design), and (2) deterioration of strength with time leading to fracture that must be prevented even if the anticipated service life is exceeded (creep-rupture design). This distinction is reflected not only in the overall level of design stresses, which will necessarily be the lower the longer the anticipated service life, but also in the reliability of the design information, primarily with respect to the behavior of the material.

In the case of structures of short or moderate life, most of the relevant design information concerning material behavior can be obtained from material tests of a duration equal to or longer than the operational life. Disregarding, for the moment, the problem of correlation of the test and the operating conditions and thus the relevance of the test data, these data are at least direct test results, subject only to a purely statistical variation, however wide. In the case of structures of anticipated long service life, the relevant material design data can be obtained only by extrapolation from tests of considerably shorter duration than the service life. The reliability of such data is therefore as doubtful as that of any extrapolation far beyond the range of actual observation, particularly as it is well known that the rate of creep and, particularly, the rate of strength deterioration are sharply accelerated by time-dependent phenomena such as oxidation and embrittlement, the full effects of which will develop only after sufficiently long periods. This latter fact also operates strongly against the acceptance of data from so-called shortened tests based on assumed "equivalence" between time and temperature, usually derived from an "equation of state." Hence, the only possible design approach is the use of extrapolated data with safety factors that increase with the anticipated operational life, to cover not only statistical variation but the uncertainty of the extrapolation. Obviously this will further increase the inherent difference in the level of design stresses between structures of short-time and long-time operation, due to the time dependence of material characteristics, with the result that the operational life and its adequate estimate emerge as a design parameter of an importance that can hardly be overestimated.

Temperature Stresses

The thermal stress problem in aeronautical engineering forms part of what is frequently referred to as "the thermal barrier" in reference to supersonic speed of flight; in nuclear engineering it actually represents the critical design problem within the reactor, while in the design of the power plant it limits the possible efficiency of operation. Although the designers of many types of structures have been faced with the existence of thermal stresses for many years, these stresses could usually be considered as secondary stresses of relatively minor importance, occurring at temperature levels at which the strength of the material is not yet affected by the temperature. The seriousness of the present thermal

stress problem arises from the fact that the severe temperature – and resulting stress – gradients occur at temperature levels at which the deformation of the material is accelerated and its resistance deteriorates while, at the same time, the inelastic response of the material and the associated stress relaxation produce stress *reversals* under *pulsating* temperatures, giving rise to "thermal fatigue."[1]

Thermal stresses may arise from different sources: (1) incompatibility of the strains $\epsilon_{ii} = \alpha T(x_i)$, where $T(x_i)$ represents the solution of the heat transfer-equation

$$\frac{\rho c}{k} \frac{\partial T}{\partial t} = \nabla^2 T + q/k \tag{1}$$

with the continuity of the medium and thus with stress-free deformation; (2) boundary restraints or boundary conditions preventing stress-free deformation under the imposed temperature field; (3) variation with temperature of the relevant thermal and mechanical properties of the continuum; and (4) inhomogeneity or anisotropy of these properties in the same material, or interaction of two materials of different properties. Linear temperature gradients do not produce thermal stresses, unless any of the sources (2), (3) or (4) are present.

Under stationary conditions without heat production the heat-transfer equation degenerates into the potential equation

$$\nabla^2 T = O \tag{2}$$

It is only under such conditions that solutions $T(x_i)$ are obtainable with relative ease. The associated stress problems are, however, of minor structural significance. The really significant transient temperature fields $T(x_i, t)$ are obtained as the solutions of the heat-transfer equation for conditions of aerodynamic heating as well as for transient conditions of heat production and heat transfer in power plants, including reactors.

The thermal gradients due to aerodynamic heating are either those existing in long time stabilized flight, due to geometry, nonuniform mass-distribution, variation with temperature of relevant thermal parameters, anisotropy of such parameters, and differences in the heat-transfer coefficients resulting from transition from laminar to turbulent flow at some point behind the leading edges of the wings, and from various disturbances, or gradients produced under conditions of acceleration and deceleration.

Gradients of the first type are quasi-stationary, but their intensity can be reduced by constructive means. On the other hand, gradients of the second type vanish after a certain time, but it is difficult to minimize them: during acceleration, skin temperatures are at a maximum, producing compression in the skin and tension in the interior; during deceleration the skin cools faster and the stress is reversed.

Thermal gradients due to heat production are of three types: (1) gradients existing during steady-state operation and heat production at constant rate; (2) gradients superimposed on gradients of type 1, resulting from

relatively slow, quasi-stationary variations of the power level due to operational requirements and action of the controls; and (3) gradients produced under conditions of start-up and shut-down, including emergency conditions.

As in the case of aerodynamic heating only the gradients of type 1 and, possibly, of type 2 can be affected by constructive means; gradients of type 3 can be affected only by the imposed rate of the start-up and shut-down process. If these rates are rapid, there arise problems that are usually referred to as "thermal shock."

The thermal fatigue and the thermal shock problems represent probably the most serious aspects of the thermal stress problem, both for aircraft and for power plants, particularly reactors, since for both types of structures repeated and rather rapid applications of temperature gradients represent normal operating conditions. However, the thermal shock problem is characteristic of the elastic response of the structure, while the thermal fatigue problem arises only as the result of the inelastic response of the material. In conjunction these problems define the critical thermal stress design conditions.

The Design Significance of Inelastic Behavior

Conventional analysis of thermal stresses is based on the assumption of a linear elastic medium with temperature-independent parameters. However, since such an assumption is no more than a crude approximation at temperatures at which the material shows even a small amount of creep, the discrepancy between the real stresses in the inelastic medium and the computed elastic stresses is considerable; it increases with increasing temperature and time-scale.

The inelastic behavior of real materials generally produces significant modifications in the elastic distribution of stresses produced by external forces; the over-all stress intensity, however, is determined essentially by the magnitude of the acting forces. With respect to the self-equilibrating thermal stresses, however, not only the distribution but the intensity itself is strongly affected by the inelastic response of the material.

The mechanical response of structural metals at elevated temperatures is a combination of elastic, viscous, and plastic components.[2]

Within different ranges of temperature and loading rate one of these components is usually predominant, permitting a certain simplification of the analysis. The three mechanical constants associated with the shear components (deviators) of such deformation, are, moreover, temperature-dependent, as are the thermal constants in the heat-transfer equations. The rigorous solution of stress problems therefore requires the establishment of the nonlinear inelastic equations with variable parameters. Solutions of such equations, however, can be obtained only under the most

drastic simplifications, such as the viscous, viscoelastic, plastic, and viscoplastic idealizations.[3]

The linear viscoelastic medium or the relaxing (Maxwell) linear viscoelastic material in the case of the simplest two-dimensional problem with equal stresses $\sigma_1 = \sigma_2$ (plate or spherical symmetry) is defined by the stress-strain relation

$$\left[\partial/\partial t + \frac{1+\nu}{1-\nu}\frac{1}{3\tau}\right]\sigma = \frac{2E}{(1-\nu)}\frac{\partial}{\partial t}(\epsilon \pm \alpha T) \tag{3}$$

where the viscosity λ, the relaxation time $\tau = \lambda/E$, the elastic modulus E and the coefficient of linear thermal expansion α are temperature-dependent.

In the case of full restraint in the direction of the stress components ($\partial\epsilon/\partial t = 0$) the temperature stresses due to a constant (steady state) temperature gradient relax toward zero. Temperature stresses can be built up only for transient conditions ($\partial T/\partial t \neq 0$).

The maximum thermal stress intensity that can be built up under such conditions depends on the ratio of the rates of the change of thermal gradient and of stress relaxation.[4] If the momentary rate of thermal stress increase due to increasing thermal gradient is slower than the momentary rate of stress relaxation, no stress increment can be formed. Therefore, the viscoelastic thermal stress at any moment is *not* proportional to the momentary thermal gradient, as in the elastic case; it depends on the history of the stress build-up. The same gradient may produce a thermal stress almost equivalent to the elastic stress or no stress at all, depending on the time available for the build-up and the temperature history that determines the history of the viscous component of the response.

If the stresses that are formed under a thermal gradient applied with sufficient slowness are very low, the removal of this gradient may produce significant stresses of opposite sign if the rate of such removal is much faster than that of its application or if, during this process, the viscosity coefficient increases, as it will at decreasing temperature. Because of this temperature sensitivity of the viscous response, a symmetrical (in time) temperature cycle will necessarily produce an unsymmetrical stress cycle.[5]

The most important consequence of this effect of viscoelastic stress relaxation is the occurence of thermal stress reversals independent of any reversal of the thermal gradient itself.[6] Thus, for instance, in the case of thermal shock on the surface of a linear viscoelastic plate the ambient temperature, the temperature difference, and the thermal stress at the surface fiber are shown as functions of time in FIGURE 1. If the ambient temperature change is of limited duration the conditions are schematically illustrated in FIGURE 2, while FIGURE 3 illustrates the conditions in the case of aerodynamic heating.

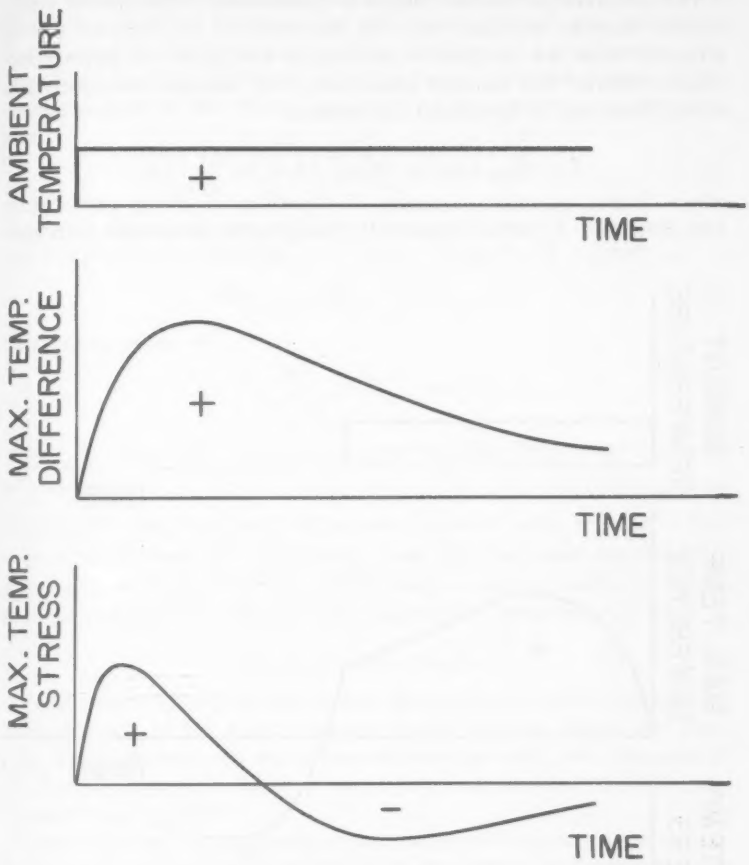

FIGURE 1. Ambient temperature, maximum temperature difference, and associated thermal stress as functions of time in a viscoelastic structure under conditions of thermal shock.[6]

FIGURES 1 to 3 illustrate the fact that because of the stress relaxation in the viscoelastic material a *transient increase* of ambient temperature may be associated with a *stress reversal.*

As the strength of structural materials under thermal stress reversal is lower than the yield limit if the number of such reversals is sufficiently large, thermal fatigue arises as a major problem in high temperature design. The rapid change of λ and, therefore, of τ with temperature will produce an intensification of the reversal with decreasing temperature.

The occurrence of thermal fatigue is independent of the type of viscoelastic response assumed; only the magnitude of the stresses will be affected. While the analysis is particularly simple for the linear viscoelastic material with constant parameters, more realistic nonlinear viscoelastic laws may be introduced, for instance

$$\frac{\partial \sigma}{\partial t} + \frac{1+\nu}{1-\nu}\frac{1}{3\tau}\left(\frac{\sigma}{\bar{\sigma}}\right)^{n-1}\sigma = \frac{2E}{1-\nu}\frac{\partial}{\partial t}(\epsilon \pm \alpha T) \qquad (4)$$

where $\bar{\sigma}$ is a constant parameter of dimension of stress and n is an odd integer $n \geq 5$, without essentially changing the phenomena discussed.

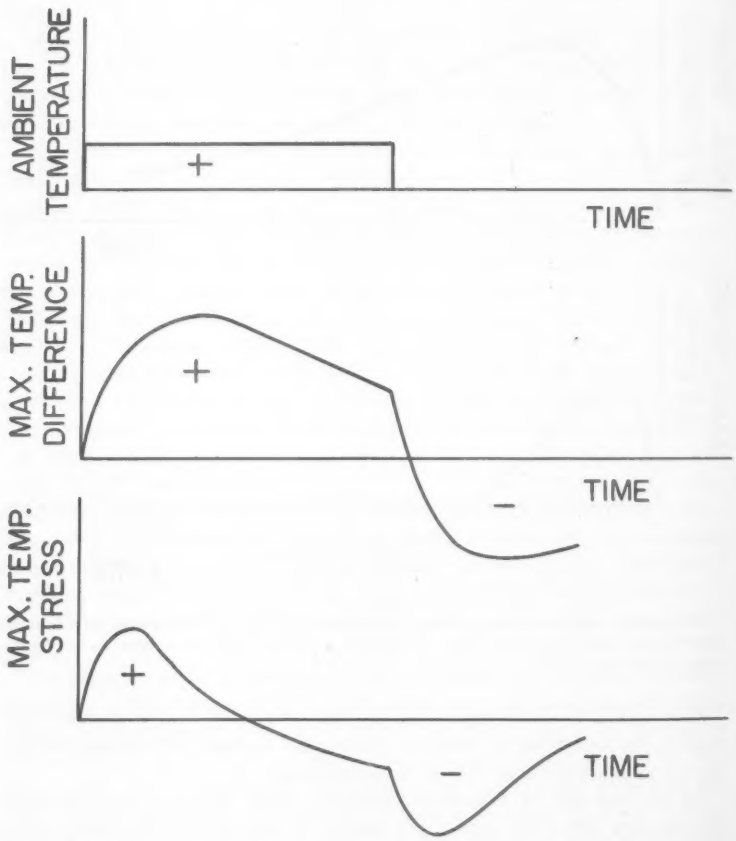

FIGURE 2. Ambient temperature, maximum temperature difference, and associated thermal stress as functions of time in a viscoelastic structure under conditions of a thermal shock cycle.

The time-dependent deformation of viscoelastic materials also strongly affects the buckling resistance of structural parts of such materials. Establishing the 1-dimensional buckling equation of a simple strut of a material of the type illustrated by EQUATION 3 from the general differential equation for the deflection w of the linear viscoelastic (Maxwell) beam[7,8]

$$EI\dot{w}_{xxxx} + \left(\frac{\partial}{\partial t} + \frac{1}{\tau}\right)\left[(Pw)_{xx} + m\dot{w} - p(x)\right] = O \qquad (5)$$

where the subscripts denote differentiation with respect to x and dots time derivatives, by assuming $\dot{w} = O$, $p(x) = O$ and $P = P_o$ = const:

$$EI\dot{w}_{xxxx} + \left(\frac{\partial}{\partial t} + \frac{1}{\tau}\right) P_o w_{xx} = O \qquad (6);$$

its solution, which is[9]

$$w = \sum_{1}^{\infty} \frac{w_o}{1 - P_o/P_{Bn}} e^{\alpha_n t/\tau} \cdot \sin(n\pi x/l) \qquad (7)$$

with $\alpha_n = 1/(P_{Bn}/P_o - 1)$ and the elastic buckling load in the nth mode $P_{\beta n} = n^2\pi^2 EI/l^2$, shows that failure is bound to occur when the combined effects of P_o and $M = P_o w(t)$ will exceed a critical value. Since M is thus a function of time, the viscoelastic strut may fail under any load P_o, provided it is applied for any period long enough to produce a lateral deflection associated with a critical value of M ("creep buckling").

The Ideal Plastic Medium

For the ideal elastic plastic medium the parallelism of the temperature difference and of the elastic thermal stress, existing below the yield limit, is broken whenever this stress exceeds the yield limit. Removal of the thermal gradient is therefore accompanied by residual stresses, producing stress reversals.

This phenomenon is illustrated by the schematic diagram in FIGURE 4. If the dependence of the yield stress on temperature is considered, the diagram FIGURE 5 is obtained.[4] FIGURE 5 shows that the decrease of the yield limit with temperature intensifies the thermal fatigue problem by increasing the amplitude of alternating plasticity.

However, the ideal elastic-plastic medium, because of its time insensitivity, does not represent a good approximation of the actual response of structural materials at elevated temperature unless the nonlinearity of the stress-strain-rate relation is much higher than can be expected in real materials under such conditions, or unless the creep rate is so small that time effects can be neglected entirely, as in the case of conventional power plants operating at moderately elevated temperatures.

For structures designed for short-time operation, as well as with respect to the infrequent short cycles of severe conditions in long-time

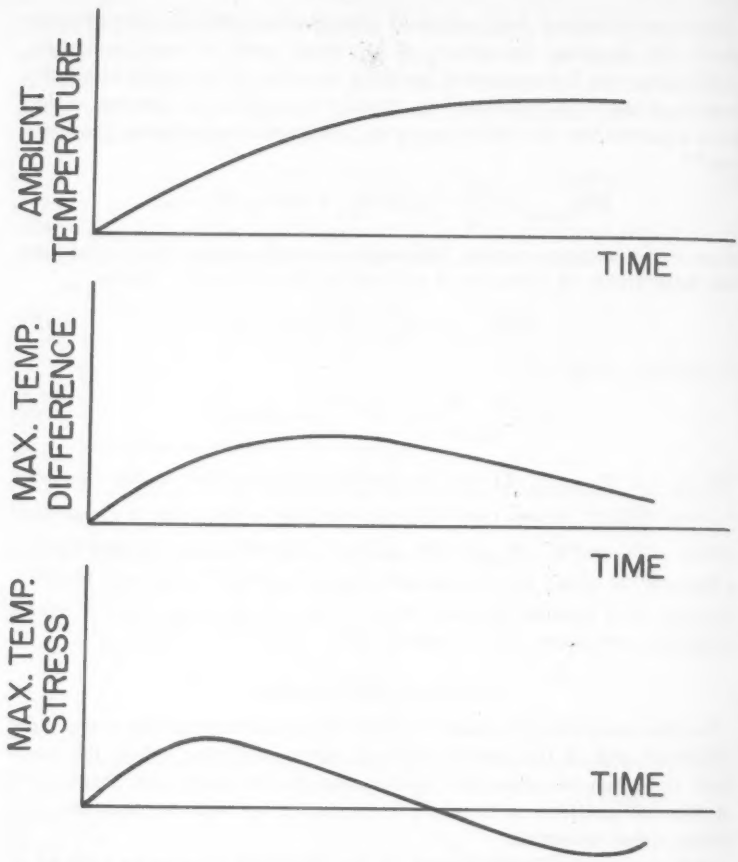

FIGURE 3. Ambient temperature, maximum temperature difference, and associated thermal stress as functions of time in a viscoelastic structure under conditions of aerodynamic heating.

operation, the situation is further complicated by the effect of the initial stage of creep at decreasing rate ("primary creep"), which requires special consideration by the introduction of particular idealizations.[10]

Interaction Between the Effects of Load and Temperature

A particular aspect of the structural analysis for high-temperature service is the effect of the various interactions between load and temperature, as distinct from the effect of temperature as an over-all parameter affecting the average properties of the structural materials. These interaction effects are of two types: (1) interaction of stress fields due

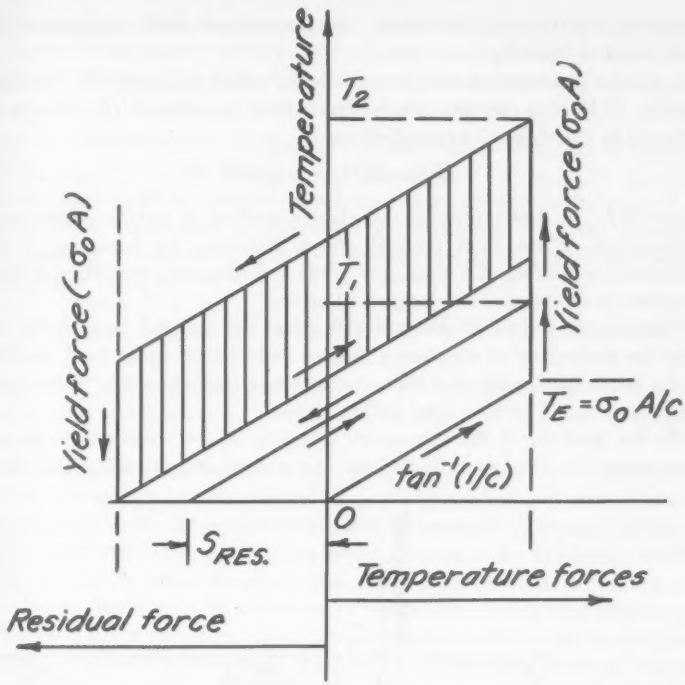

FIGURE 4. Relation between temperature and temperature force in a restrained elastic-plastic bar.[4]

to load and to temperature; and (2) interaction due to inhomogeneous change of mechanical properties by nonhomogeneous temperature fields.

Effects of the first type. These effects arise, for instance, in the case of elastic vibrations of structures subject to a thermal stress field and can be illustrated simply by the example of the vibration of a hinged strut with natural frequencies of the n modes given by $\omega_n = n^2\pi^2 (cr)$ where $c = \sqrt{E/\rho}$ and the radius of gyration $r^2 = I/A$. If this strut is subject to an over-all uniform temperature change T, its free expansion or contraction being prevented, the natural frequencies of the strut are affected by the positive or negative temperature thrust $P(t) = \pm E\alpha AT(t)$ according to the equation

$$\omega_n'(t) = \omega_n \sqrt{1 \mp \frac{\alpha^2}{n^2}} \tag{8}$$

where $\alpha^2(t) = P(t)/P_B$. Thus, the frequency is reduced (permanently or temporarily, depending on whether the thermal force is stationary or transient) by temperature increase and increased by temperature reduction,

the more significantly the closer the temperature force approaches the first buckling load P_B.

A similar phenomenon arises in torsional vibrations where the torsional rigidity (GJ) of a section which determines its natural frequencies is affected by the thermal stress field σ_T.[11]

$$(GJ) = (GJ)_o - \int \sigma_T r^2 dA \tag{9}$$

where $(GJ)_o$ is the rigidity of the elastic section at constant (reference) temperature. A transient thermal stress field as, for instance, in the aerodynamic heating of a wing, may produce a temporary reduction of (GJ), temporarily increasing the danger of flutter.

Temperature forces or stresses will affect not only the frequencies, but also the deflection of structures (beams and plates) under load, because of the second-order bending moments resulting from the temperature forces multiplied by the primary load deflections.

On the other hand, the momentary intensity of the temperature stresses themselves is strongly affected by the extent of inelastic deformation

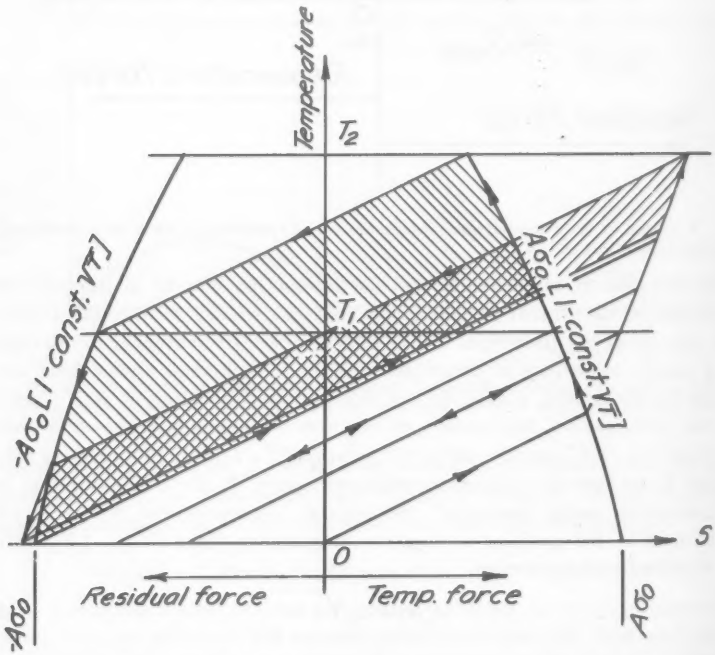

FIGURE 5. Relation between temperature and temperature force in a restrained elastic-plastic and elastic-workhardening bar with temperature-dependent yield limit.[4]

present within the structure. Thus, for instance, considering that the constant temperature moment and maximum temperature stress in a restrained elastic plate under a linear temperature difference T is

$$M = \alpha T D (1+\nu) \text{ and } \sigma = \pm 2 ET/2(1-\nu) \quad (10)$$

with $D = Ed^2/12(1-\nu)$, it is obvious that the gradual reduction of the depth of the elastic core for temperature differences $T > T_o = 2\sigma_o(1-\nu)/\alpha E$ at which yielding starts, will considerably reduce the rate of build-up of the temperature moment M by reducing the "stiffness" D with increasing temperature difference T. It can be shown[6] that in this range the relation between M and T is

$$M = M_{FL}\left[1 - \frac{1}{3}(T_o/T)^2\right] \text{ and therefore } dM/dT = \frac{1}{T_o}\frac{2}{3} M_{FL}(T_o/T)^3 \quad (11)$$

where M_{FL} is the plastic capacity moment of the plate. Thus, the plastic resistance of the sections can never be attained by temperature moments alone.

If, in addition to temperature moments, normal forces are acting in the plate, which might be considered as part of a cylinder or of a sphere of large radius under the action of internal or external pressure, yielding on one side of the plate would occur under a temperature difference smaller than T_o, and it would be above this reduced temperature difference that the further build-up of temperature moments with increasing temperature difference would be slowed down, the more sharply the higher the stresses under the normal forces due to the load. It is obvious, however, that the price to be paid for such reduction of the temperature moments is the increasing severity of the residual stresses, and thus of the effects of thermal fatigue or of "alternating plasticity."

Effects of the second type. These effects are mainly the results of the fact that the rates of creep and of relaxation in metals at elevated temperatures are extremely temperature-sensitive. Thus, even without consideration of the associated thermal stress field, the inhomogeneous temperature field alone will seriously change the distribution of the stresses produced by applied forces.

Considering, for instance, a thin nonlinear incompressible viscoelastic plate forming part of a large sphere of radius R under internal pressure, with gradually changing linear temperature gradient $\Delta T = \Delta \overline{T}\,\frac{x}{d}\,f(t/t_o)$ across the wall of thickness d, where t_o is a reference time, the problem can be approximated by the analysis of a flat plate under the action of normal stresses $\sigma_{11} = \sigma_{22} = \sigma = pR/2d$ while $0 < \sigma_{33} < p$ can be neglected in comparison. The temperature variation of the coefficient of viscosity λ is introduced in the standard form[2]

$$\lambda = \lambda_o e^{Q/R\left(\frac{1}{T} - \frac{1}{T_o}\right)} = \lambda_o e^{-Q/RT_o(\Delta T/T)} \doteq \lambda_o e^{-Q/RT_o(\Delta T/T_o)} \quad (12)$$

where T and the reference temperature T_o are expressed in degrees Kelvin and $\Delta T = T - T_o$, while the temperature variation of the elastic modulus is neglected. Hence EQUATION 4 can be written in the form (with $\xi = \frac{x}{d}$)

$$\frac{\partial \sigma}{\partial t} + \tau_o^{-1} e^{a(t)\xi} \left(\frac{\sigma}{\overline{\sigma}}\right)^{n-1} \sigma = 4E \frac{\partial \epsilon}{\partial t} + b(t)\xi \tag{13}$$

where

$$a(t) = Q/RT_o \, (\Delta \overline{T}/T_o) f(t/t_o) \text{ and } b(t) = 4E \, \alpha \dot{f}(t) \Delta \overline{T} \tag{13a}$$

The solution of EQUATION 13 is obtainable only for the linear case of $n = 1$ and for long times or very simple temperature-history functions $f(t)$, and leads to expressions containing tabulated functions (exponential integrals). Because of the high nonlinearity of behavior of metals at elevated temperatures such solutions are of relatively small practical importance. While solutions of the nonlinear equation may be possible under specific assumptions, some information concerning the general problem is obtained by considering an asymptotic stationary state $f(t) = 1$, when the temperature stress has been completely relaxed and the motion proceeds at a uniform constant rate ϵ_o, while $\partial \sigma / \partial t = O$. Under these conditions the normal (load) stresses in the plate are easily found to be

$$\sigma = \sigma_o \frac{(a/2n)}{\sin h \, (a/2n)} e^{-\frac{a}{n}\xi} \tag{14}$$

where $\sigma_o = pR/2d$ is the uniform stress without temperature-interaction. The maximum stress is at $\xi = -\frac{1}{2}$ (cold fiber), the minimum stress at $\xi = +\frac{1}{2}$ (hot fiber); their ratio is $\sigma_{max.}/\sigma_{min.} = e^{a/n}$. For instance, with $Q = 80{,}000$ cal./mole, $R = 2$ cal./mole, $T = 800°$ K., $\Delta T = 0.10\ T = 80°$C. the coefficient $a = 5.0$. The following stress ratios are therefore obtained for various nonlinearities expressed by the power n:

n	$\sigma_{max.}/\sigma_o$	$\sigma_{min.}/\sigma_o$	$\sigma_{max.}/\sigma_{min.}$
1	5.03	0.03	1.48
3	1.98	0.39	5.30
5	1.59	0.59	2.72
7	1.40	0.69	2.04
∞	1.00	1.00	1.00

The effect of the temperature field on the load stresses thus is not insignificant even if the nonlinearity is high; the assumption of linearity, however, leads to unrealistic results. Different temperature gradients produce different effects on the stress distribution. The more inhomogeneous the temperature field, the more pronounced its effect on the stress field; but high values $\Delta \overline{T}$ can be compensated by high nonlinearity n.

The redistribution of load stresses due to the nonhomogeneous temperature field also adversely affects the bending resistance of structures

with such temperature fields, as well as their buckling strength: the transfer of the stresses toward the cold edge and the resulting motion of the neutral axis in bending toward this edge, associated with a rapid increase of the maximum cold-fiber stress and of the rate of creep, reduce the apparent bending rigidity of the structure and increase the excentricity of any acting compressive force, producing rapid collapse under the increasingly eccentric compression. The solution of EQUATION 13 for stationary conditions of bending under the Navier assumption of plane sections in the form $\dot{\epsilon} = \dot{\Delta}\,(\xi - \xi_o)$, where $\dot{\Delta}$ is the sum of the extreme fiber strain rates, and $\xi_o = x_o/d$ the parameter of the stationary location of the neutral axis, is cumbersome, but elementary. Once this location has been established from the condition that across the bent section $\int \sigma d\xi = 0$, the relation between the bending moment M and the stress distribution follows from $\int \sigma(\xi - \xi_o) d\xi = M$ (FIGURE 6).

Selection of Structural Materials

The selection of the structural material strongly affects the intensity of the thermal stress field that is being built up, since this intensity is proportional to $E\alpha/k(1-\nu) = v_1$, which can therefore be considered as a quality figure of the material. The resistance to thermal stresses at various temperatures depends on the rate of reduction with temperature of the creep strength of the material, which is of the general form $\sigma = \sigma_o(t) \exp[1 - c \log(T/T_o)] = \sigma_o(t) v_2$, where $\sigma_o(t)$ is the time strength at the

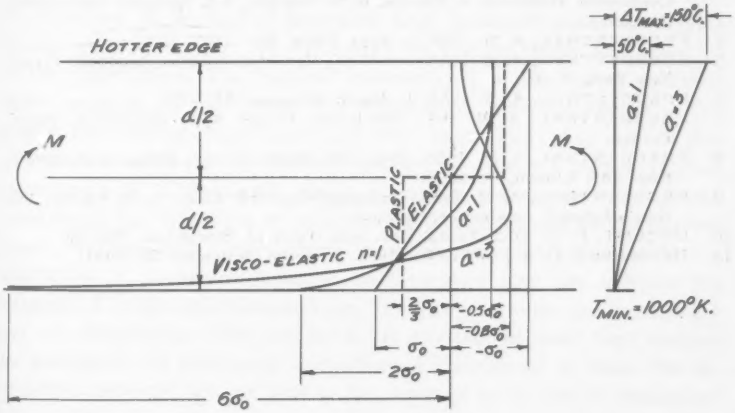

FIGURE 6. Stationary stress distribution in rectangular viscoelastic beam under the joint effect of a constant bending moment M and temperature gradients $a = 1$ and $a = 3$. ("Elastic" distribution is equivalent to $a = 0$, linear "viscoelastic" for $n = 1$, $a = 1$ and $a = 3$ is roughly equivalent to nonlinear for $a/n = 1$ and $a/n = 3$ provided $a > 1$ and $n > 1$, "plastic" distribution is reached for arbitrary a as $n \to \infty$.)

reference temperature T_o; v_2 represents a second quality figure. The combined quality figure for high-temperature performance of materials $[v_1/\sigma_o(t)v_2]$ provides a rating figure on the basis of which various materials can be compared for various operational lives t and temperatures T. For the design of reactor parts the above figure is multiplied by the capture cross section for thermal neutrons to obtain a rating figure including the nuclear properties.[1] It is obvious that the rating figures will differ for various temperature levels at the same operating life.

The economic aspect can be included by multiplying the quality figure $(v_1/\sigma_o(t)v_2)$ by a unit cost factor that may significantly affect the relative rating, since the present relation between the unit cost of regular low-alloy steels, used up to 800° F., iron-base alloys (stainless steels), used up to 1500° F., nickel-base alloys used up to 1800° F., and cobalt- or molybdenum-base alloys used between 1600° F. and 2200° F., is roughly of the order of magnitude of 1 : 5 : 15 : 35. This aspect, however important it may appear, can be considered only in conjunction with the performance limitations of the various types of high-temperature materials.

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APPLICATIONS OF INFORMATION THEORY IN EXPERIMENTAL PSYCHOLOGY*

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Information theory is one of the outstanding intellectual novelties of our day. It was fashioned in 1948 as a mathematical tool of electronic communication, but its impact was immediately felt all over the scientific world. Its importance seems to grow year by year. This in itself is something of an intellectual curiosity, for information theory has been more distinguished for what it has promised than for what it has delivered.

By now nearly everyone knows that the basic questions in information theory were proposed in an early paper by Hartley in 1928,[1] and that the classic formulation of the theory was made by Shannon in 1948.[2] Within five years of Shannon's paper, applications of information theory had appeared in fields as divergent as physics, economics, and psychiatry. The literature continues to accumulate at an enormous rate. In this paper I should like to discuss applications of information theory in experimental psychology. The same thing might have been done by a like representative of any one of a half dozen different specialized areas.

Why has information theory attracted so much attention? One answer to this question is that in some curious way the theory has become associated with statistical decision theory and with computer design. These two branches of applied mathematics have produced some astonishing achievements in the last ten years, and information theory has benefited by the association. The original contributions of the theory in these areas, however, do not appear to be substantial. A second answer is that models for communication have very wide application. Any system that influences the behavior of another system, by whatever means, is communicating with it. Hence the stimulus-response paradigm of experimental psychology, the black box of electrical engineering, and even the functional analysis that characterizes an experiment are all amenable to description in a common language. Information theory has provided the language. Finally, information theory has given us some important measures of organization. New measures are exciting because they suggest the possibility of previously undiscovered invariances in data. But information measures are not new in the sense of being radical departures from earlier ideas. Furthermore, they are highly restricted and improper in many situations of genuine interest to psychologists. I am suggesting that information theory's power to excite us is an amalgam of mediocre attractions: a superficial association with computer models and brain

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models; a seeming connection with problems in one's own field; and a group of measures to test out on our data. These measures, if they are not new, are at least untried. I cannot speak for other fields, but I do know that experimental psychologists were swept by a wave of excitement for information theory that had, roughly, these dimensions. Now we are experiencing the afterperiod of critical analysis. What will remain when the bandwagon (to use Shannon's ironic metaphor) has stopped rolling? The outlines are beginning to appear, and the balance of this paper will be devoted to sketching them as they now appear to me.

Information in the sense of information theory is not the sort of information with which we are familiar. We ordinarily think of information as a collection of facts, a file of meaningful data. The key to Shannon's success was precisely that he deliberately avoided any questions of meaning. A communication system is a slave to its inputs. Its task is not to understand, but merely to transmit them. If the inputs are reproduced at the receiving end with desired fidelity, the communication system has done its work. Yet a system that responds instantly and equally to all possible inputs behaves stupidly unless the inputs are completely unpredictable. When the inputs are more or less predictable, the communication system can operate so as to take advantage of this predictability by reducing storage capacity, by employing suitable coding against the effects of noise, and by using the predictability to check errors. Accordingly, a communication system responds with some cleverness to the predictability of the symbols it must transmit, but not to their meanings. This is literally true, and still it is very difficult to study Shannon's statistical approximations to English without feeling that he has contributed a good deal to the psychology of meaning.

The theory provides ways of measuring the predictability of events with which a communication channel must deal. It then formulates some criteria of good performance. For example, the channel statistics may be chosen so that the theory transmits maximum information, or so that it transmits information at a fixed average rate with minimum possible error. Finally, the theory deduces some rather surprising theorems about the performance of communication channels in terms of these measures and these criteria.

Psychologists have made very little use of the performance criteria and of the basic theorems of information theory. For the most part these aspects of the theory are either too restricted or too general to have any direct application in experimental psychology. Psychologists *have* been tremendously stimulated by Shannon's information measures. They have used these measures to obtain information rates in various human motor performances and to measure the information capacity of sensory channels. Beyond this, the information measures have made possible a new and

interesting quantitative treatment of such topics as verbal behavior, concept formation, and psychophysical judgments.

Information measures have a familiar ring to anyone with even an amateur's grasp of statistics. They describe variability but, unlike our most familiar tool, variance, Shannon's measures are nonmetric. Anything that can be specified in categorical terms may be measured with this new yardstick. The building block of informational variability is the "bit." A bit is a logarithmic unit that specifies the amount of information spanned by two equally likely alternatives. Four alternatives measure 2 bits. Eight alternatives measure 3 bits and so on. As the number of alternatives increases by powers of two, the bit measure increases by unity. Since the alternatives are uncertain and, since any one may occur, the bit measure reflects the uncertainty, that is, the variability of predicting which particular alternative will occur. A log unit is demanded because two independent choices, each from 2 alternatives (2 bits), are equivalent to one choice from 4 alternatives (2 bits). The general expression for the bit measure over a set of categories is Shannon's famous H-function

$$H(x) = -\sum_k p(k) \log_2 p(k)$$

The discrete categorical distribution is labeled x. The probability that an event falls in the kth category of x is $p(k)$. The sum over all probabilities is unity, and the minus sign merely corrects the negative sign of the logarithm. $H(x)$ is measured in bits and is always positive. If all the probability is concentrated in a single discrete category, $H(x)$ is equal to zero. When the probabilities are spread out uniformly over all the categories, $H(x)$ is maximum.

In communication theory, x is a source of signals each of which has some predetermined probability. In psychology the idea of a signal source is broadened to include a wide variety of interesting events. Such things as numbers, words, judgments, positions on a grid, and neural responses readily qualify.

The bit measure lends itself easily to conditional restrictions. Suppose that the probabilities in x are conditional. These probabilities depend on the state in which the communication channel finds itself. If we think of the x categories as response categories, then the conditional case of which we speak occurs, for example, when the probabilities of the responses depend on the stimulus that has occurred. The H-formula is now measured over a matrix of conditional probabilities.

$$H_w(x) = -\sum_j p(j) \sum_k p_j(k) \log_2 p_j(k)$$

The categorization x is now said to be conditional on the categorization w. The difference between these two measures, $H(x) - H_w(x)$, is a specific

number determined by the joint probability distribution over the categories of w and x. This quantity is symbolized by

$$T(w:x) \quad H(x) - H_w(x)$$

It is called transmitted information and it is a most important quantity in information measurement. This quantity is the direct analogue of correlation in classical statistics except for the fact that it is nonmetric. We see that Shannon requires as evidence of communication only that the output of the channel be correlated with the input, nothing more. This brief discussion cannot hope to make it clear (but it does suggest) that there is nothing in information theory that is not already contained in probability theory. The information measures provide a summary statistic over a probability space. We cheerfully add it to our logical artillery for describing probability distributions; however, the new weapon belongs in our conventional armament. It is not an H-Bomb!

In much of the psychological work, the human being is considered as a communication channel and measurements of $T(w:x)$ information transmission are made through him. The basic idea is illustrated in the following typical experiment. A listener must identify a set of tones by assigning numbers to them. All tones are identical in frequency, but differ in loudness. The loudness range is kept constant and is cut up finer and finer as the number of different stimuli that O must judge is increased. Information transmission is measured in terms of the accuracy of O's identifications as a function of the number of stimulus categories. As the latter increases, the transmitted information increases and then levels off at a maximum. This implies that each increase in input information, after the maximum transmission is reached, is accompanied by an equivalent increase in O's errors and confusions. The finding is an empirical one. The interesting thing about it is that the average O transmits surprisingly little information; about 2.3 bits[3] in his loudness judgments. This figure is equivalent to approximately 5 perfectly discriminated loudnesses. Apparently the average observer's loudness channel has a natural capacity that is quite small when determined empirically.

The kind of measurement of "channel capacity" just described is the obvious one in psychology. It does not appear to be the channel capacity defined by Shannon in information theory. The latter involves the restriction that channel noise remain constant, whereas the noise in O's discriminations varies in proportion to the amount of input information. However, the low-level capacity of discrimination channels is an interesting and general phenomenon. G. A. Miller has summarized the principal results in a recent paper.[4] His discussion covers discrimination of pitch, loudness, taste, hue, brightness, vibration, points on a line (linear extent), direction, and curvature of lines. The measured capacities vary from 1.6 bits for curvature to 3.9 bits for linear extent. The mean is 2.6 bits with a standard deviation of only 0.6 bits. The measure-

ments in bits correspond to a mean of 6.5 categories (the magical number 7). The standard deviation includes from 4 to 10 categories. Pollack,[5] who was responsible for much of the research summarized by Miller, has pointed out that this sort of performance is hardly in keeping with our intuition. After all, nearly every one of us can identify thousands of faces and voices. In a very interesting experiment, Pollack has shown that absolute discriminations can be pushed above 7.2 bits corresponding to about 150 perfect discriminations. Pollack accomplished this by having his subjects make a few discriminations on many different acoustical continua, rather than many discriminations on a single dimension. Following Pollack's reasoning we might say that all monkeys look alike to people because we cannot make many discriminations on a single dimension of "monkeyness." When we are able to distinguish one monkey from another, it is because we can make discriminations along separate monkey continua of shape, size, color, and only a few discriminations on several dimensions are enough to tell many monkeys apart.

It is worth repeating here that the foregoing are important generalizations about discrimination, but the "channel capacities" on which the generalizations are based have nothing to do with information theory. The channel capacities have been formulated in terms of information measures and for this purpose the information measures are certainly handy, but again the information measures are in no way essential to the measurement of empirical channel capacity. The same results could have been achieved via a mundane statistic such as the contingency coefficient. The role of information theory here has been to suggest the problem rather than to provide a vital element in its solution.

In the experiments just described the magical number was approximately 7. It represents the average number of perfectly discriminated alternatives when subjects are asked to identify stimuli that vary on the same stimulus dimension. Suppose now we ask our subject to do this repeatedly as rapidly as possible. If *O* generates 2.6 bits per judgment and makes, let us say, 3 judgments per second, what is his transmission rate in bits/sec.? Let us ignore for the moment our previous argument that these measurements are really irrelevant. The performance rates at 7.8 bits/sec. and we should say that our observer transmits information at this rate. Actually this experiment is generally not done because it yields miniscule rates. Instead, psychologists have relied on the principle of the one-man band. The basic idea is this. A good typist can transmit information through her fingers to the typewriter at a high production rate. To a certain extent this production is possible because English is from 60 to 80 per cent redundant. When she is required to type letters at random, the typist proceeds more slowly. Now, however, the information per symbol of the alphabet is much higher, and her information rate in bits/sec. is also possibly higher. The problem is to find the maximum

output in bits/sec. when we are free to choose stimuli, responses, and conditions at will.

The typist transcribing random symbols has been studied by Quastler,[6] who provided a copy sheet so that errors could be checked and then told the typists to do their utmost. The maximum rate for 7 good typists was 17 bits/sec. accomplished by driving them at speeds beyond their best accuracy. This is equivalent to typing English at speeds of from 116 to 160 words/min. (the wide range in the estimated rate is due to the variability in our estimates of the redundancy of English). Quastler obtained a maximum rate of 22 bits/sec. from skilled pianists playing random music at sight. Licklider obtained rates of from 25 to 40 bits/sec. by having practised subjects read words selected at random from the Oxford dictionary, while simultaneously performing another motor task.[7] Licklider estimates the maximum attainable information rate at about 50 bits/sec.

Now we have another magical number. It is hard to see that this number has much practical or theoretical significance to psychologists except in a suggestive way. This suggestion takes the following form. It has been estimated that a sensory nerve transmits more than 1000 bits of information per second.[8] Since the total output is so small (approximately 50 bits/sec.), a very large part of the performance loop in the nervous system must be devoted to coding and error checking via redundancy. In any case it is perfectly evident why engineers deprecate the human being as a routine mechanical performer when they consider that an ordinary telephone channel has a capacity of transmitting about 28,000 bits/sec. In fact, a figure of the order of billions of bits/sec. is not at all unreasonable in systems processing complex data.

We now return to the question of the part that information theory has played in the production of the magic number 50. Admittedly, there was little interest in evaluating performance maxima before information theory evolved. The information measures have provided a bridge connecting the human system for processing data with machine systems and have made it possible and valuable to compare the numbers. On the other hand, information theory neither suggested the tasks nor told us how to extend the maxima beyond limits we already knew. This potentiality may develop out of future work, but there is currently no hint of how it will be accomplished or of what part information theory will play in it. Once again we seem to see the theory play its familiar role of rationalizing and integrating what is already known on other grounds.

Lest I convey the wrong impression, there are some areas of experimental psychology in which the contribution of information theory appears to be both genuine and unique. In order to balance the picture, let us now consider these. The most important work is found in G. A. Miller's studies of verbal context.[9, 10, 11] Miller is explicitly interested in communication. He has shown that letters and words are identified more easily

and accurately when they are more predictable. In one study made in collaboration with Bruner and Postman,[9] Miller required his subjects to write down 60 pseudowords constructed out of 8 letters and exposed for brief time intervals in a tachistoscope. The words were put together by Shannon's rules for statistical approximation to English. Fifteen words were made from random letters. Fifteen were made with letters having the probabilities of letters in English. Fifteen were made with the probabilities of pairs of English letters. The last 15 were constructed to match the probabilities of sets of 4 letters in English. The point of this experiment was that the fourth-order approximations to English were easiest to recognize, and that the second-order, first-order, and zero-order approximations ranked behind in that sequence. Surprisingly, however, when the data were corrected for the relative amounts of information per letter, the differences disappeared. This means specifically that the ability to recognize letters was invariant with the amount of information in the letters. Shannon's computations of the redundancy of English were a vital part of this result; many other ways to compute redundancy would not have yielded the same results. For the first time we see in psychology an application of information theory that seems genuinely to depend on information theory and is not merely an old song sung to a new tune.

Even in some of Miller's work the role of information theory is simply that of reminding us that the subject's performance in recognizing words depends on the number of alternatives from which the word is drawn. We were perhaps not as aware of this as we should have been, and the information measure certainly has helped us to give a clear specification of the number of choices confronting *S* at any time. This advantage is most obvious in recent studies of concept formation.[12] Nevertheless, we should not confuse stimulus alternatives with stimulus information. Many psychologically different situations are indistinguishable in terms of information measures.

One of the few papers to consider the potentialities of the information measure for generating different experimental conditions was Hyman's study of reaction time.[13] It is generally known that reaction time depends on the number of stimulus alternatives. Hyman showed that reaction time is determined by the amount of information in the stimulus. The latter depends on the number of stimulus alternatives, but also on their probabilities and conditional probabilities. Hyman varied all 3 and still found, in 3 out of 4 subjects, that reaction time is determined by stimulus information rather than by the number of stimulus alternatives.

This reviewer's opinion is that the most significant contribution of information theory to experimental psychology has been its gift of a new set of nonmetric statistics. I have already noted that the information measures are not radically new. Information measures are clearly in the spiritual heritage of the classical statistical measures of variability and

correlation. The experimental psychologists have become interested in them because the information measures provide a partition of chi-square and, hence, of frequency data that is almost a literal parallel to analysis of variance. Accordingly it is now possible to analyze categorical data much more completely than has been possible in the past.

Studies of absolute judgments have succeeded in revealing how S's guessing habits interact with his judgments at threshold,[14] and how S's reinforcement history influences his guessing habits.[15]

We are beginning to get a more complete picture of threshold data than we have ever had before, and the information measure has proved invaluable in this connection. The application, however, has nothing to do with information theory. Recent work makes it appear that the chi-square analysis can be worked out either with sums of squared frequencies or with logged frequencies.[16] Hence it appears that the mathematics of information theory have broad statistical applications through their relation with the likelihood ratio and chi-square. These applications may be as important as the theory. In the minds of many researchers the mathematics and the theory are one. I do not think so. The fundamental theorem of information theory in the case of a noisy channel seems to me to be a direct application of the strong law of large numbers, an application that does not depend on Shannon's choice of mathematical expression. Similarly, mean log probability appears to be a close relative – at least a first cousin – to the likelihood ratio and would be important even if there were no theory. The somewhat fortuitous marriage of the information measures and information theory may, in the long run, prove to have confused psychologists as much as it has stimulated them.

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*SECTION OF OCEANOGRAPHY AND METEOROLOGY**

THE ATMOSPHERE OF THE PLANET MARS*

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Mars is of special interest to us on the earth because it is the closest of all the planets, except Venus, and it is the next removed in distance from the sun. These circumstances combine to offer unparalleled opportunities for telescopic study when Mars is opposite us from the sun. These occasions come at intervals of about two years, and they are called "oppositions." In 1954 and 1956 Mars came especially close to the earth. Because of the greater eccentricity of Mars' orbit about the sun, the oppositions will not be as favorable for many years to come. The next really close approach of the two planets will occur in 1971.

From a meteorological point of view Mars is also of great interest because it resembles the earth in a number of important respects. For example, Mars rotates on its axis with a period of 24 hr., 37 min., and 22.6 sec., which is only slightly more than our own daily period, and Mars' equator is inclined with respect to the plane of its orbit around the sun by 25° 12′, which is close to the terrestrial value of 23° 27′. Therefore, we expect similar Coriolis and seasonal effects on Mars and on the earth.

Some of the differences between the two planets suggest that a study of Mars might throw light on the meteorological effects of variations in these parameters. Mars' period of revolution about the sun is 1.88 of our years, so the seasons will be nearly twice as long. The radius of the planet is 0.53 of ours, and the acceleration of gravity is only 380 cm. s^{-2}. Thus, the adiabatic lapse rate (in a nitrogen atmosphere) is only 3.7° C. $km.^{-1}$ compared to the terrestrial value of 9.8° C. $km.^{-1}$

Visual and photographic observations confirm some of the expectations to which these data lead. In yellow and red light one can see and record a complex system of dark markings and areas against a reddish-orange background on the planetary surface. These dark markings are mostly fixed in position and have been known and mapped for many years. Some of them exhibit a marked seasonal variation: during winter they are small and not very dark; as summer approaches they grow in size and darken. This behavior has long been interpreted as signifying the existence of plant life on Mars. In addition, there are distinct white polar caps that wax and wane with the seasons.

*This paper, illustrated with lantern slides, was presented at a meeting of the Section on January 22, 1957.

The composition of the atmosphere has been studied spectroscopically for many years, but with few positive results. The presence of carbon dioxide has been established (Kuiper, 1949) by means of its absorption at 1.6 μ. Recently the pressure dependence of CO_2 absorption has been taken into account (Goody and Grandjean, 1955) in dealing with Kuiper's data. They estimate that Mars' atmosphere contains about thirteen times the mass of CO_2 per unit area in our atmosphere. Water vapor must be present because the polar ice caps, whose seasonal waxing and waning are obvious, are composed of frozen water. This is known from the infrared reflection spectrum of the caps (Kuiper, 1949). However, all modern attempts to detect this water vapor spectroscopically have failed. This is in part due to the difficulty of observation through our own moist air, and to the fact that the pressure dependence of water vapor absorption minimizes the Martian contribution. Nevertheless, this negative result must be due primarily to the very small amount of vapor in the Martian atmosphere. It is likely that surface frost points are near -90° C., which means that the atmosphere is far more arid than at any place on the surface of the earth.

No other gases have given either direct or indirect spectroscopic evidence of their presence. Oxygen in particular is absent. However, argon very likely exists on Mars. Our own argon was generated largely by radioactive decay of K^{40}. Since Mars should have received its share of K^{40}, and since argon is too heavy to have been lost to space completely and chemically is completely inert, it may be assumed to be present. A similar argument can be offered for nitrogen, which is cosmically abundant, chemically rather inert, and sufficiently heavy to have avoided complete loss to space. As we shall see, it is likely that nitrogen is the predominant constituent of Mars' atmosphere. Nitrogen is followed in order by argon, carbon dioxide, and water. Unfortunately, argon and nitrogen have no absorptions in accessible parts of the spectrum.

The total amount of atmosphere has been estimated by a variety of techniques, primarily optical (de Vaucouleurs, 1954). The results are not very accurate, but we can say with a certain degree of assurance that the surface pressure is 50 to 100 mb. This means about 125 to 250 g. $cm.^{-2}$ of air compared to about 1000 g. $cm.^{-2}$ on the earth. The Martian atmosphere is appreciably thinner than our own. If one estimates the amounts of argon and carbon dioxide (water vapor is negligible) one finds they account for only 10 per cent of the mass. Thus the atmosphere of Mars probably is composed mostly of nitrogen.

The surface temperature of the sunlit part of Mars is well known through the radiometric studies of Coblentz and Lampland (1927) and of Pettit and Nicholson (1924). The procedure in such measurements is to mount a tiny, blackened thermocouple in the focal plane of a reflecting telescope. When the image of the planet is superimposed on this radiation receiver

the thermocouple temperature rises as the total emitted infrared and reflected short wave energies are absorbed. Then a filter (usually a liquid-water cell) is placed in the beam to cut out the infrared component. From the difference between the potentials generated by the thermocouple in these two cases, it is possible to calculate the rate of emission of long-wave energy by the planet's surface. It is then simple to calculate the temperature that a black body must have in order to emit at this rate. It has proved possible to make and use thermocouple junctions so tiny that the radiation may be measured consistently from a Martian area as small as 200 miles in radius. This has permitted meteorologists to draw temperature maps for Mars (Hess, 1950; Gifford, Jr., 1956). One of these maps, for the southern hemisphere in summer, is shown in FIGURE 1. These are temperatures measured along the planet's central meridian, and they represent essentially the diurnal maximum temperatures. These data indicate that the surface temperature may rise to 30° C. or more near the thermal equator, but that a strong latitudinal temperature gradient exists, especially in the winter hemisphere. One may calculate the vertical geostrophic wind shear from the thermal wind relationship, using the values of the pertinent parameters that are appropriate to Mars. Such a calculation indicates wind shears somewhat smaller than those on the earth. This means, in turn, that the zonal circulation on Mars is slower than our own.

The diurnal variation of temperature is not completely known. Near the equator, as we have seen, the temperature rises well above 0° C. This

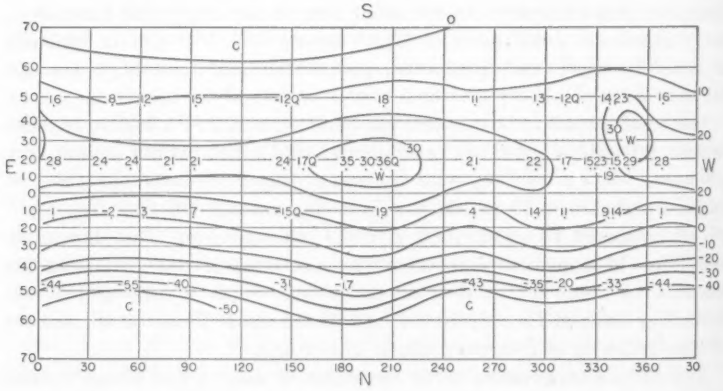

FIGURE 1. The distribution of temperature (centigrade) on Mars in northern hemisphere winter. This is the telescopic view with south at the top. To obtain the usual view merely invert the page. The points marked *Q* are questionable either through being interpolated values or because of the presence of clouds.

occurs about one hour after local noon. The minimum temperatures at night cannot be observed for purely geometric reasons, but observations close to the morning limb indicate equatorial temperatures near -40° C. It is not unlikely that the night-time temperatures may fall to -80° or -90° C.

The atmosphere of Mars exhibits a variety of clouds of various types. The first type is a cloud, detectable in yellow or red light, that is visible because it obscures the normal pattern of surface planetary markings. These clouds are common near the limbs of the planet. Here they are probably ice clouds close to the surface formed by sublimation of the meager water vapor because of the very low night temperatures. These visible clouds occur also near the center of the disk, but far less frequently than near the edges. They may be either dust or convective H_2O clouds. Sometimes they appear yellowish, in which case they are probably dust. At other times they are white and are probably ice.

Still another kind of cloud is detectable on photographs taken in blue light. In such photographs one normally cannot distinguish any of the surface features except the polar cap. At first it was thought that in blue light the contrast of the bluish dark areas against the reddish "desert" areas had decreased to nearly zero, thus making it impossible to record any distinction. This hypothesis was disproved in 1937 when there was obtained a blue photograph that showed the surface configurations (Slipher, 1937). The current belief is that a haze or cloud layer composed of very small particles is normally present on Mars. This scatters blue light more effectively than yellow or red light and so obscures the surface in short wave lengths, but not in longer ones. This layer is commonly referred to as the "blue haze." The 1937 blue photograph can then be explained as being due to a clearing of this haze. This "blue clearing" has been recorded at a number of oppositions since 1937 and is well established. The polarization of the scattered blue light suggests that the mean particle radius is in the vicinity of 0.2 μ. Three possible explanations of the blue haze immediately suggest themselves. The blue haze may be: (1) dust; (2) H_2O ice; or (3) CO_2 ice. The first may be dismissed immediately because the only way a clearing could then occur would be for the dust to settle to the ground gravitationally. The terminal velocity on Mars of spheres with a radius of 0.2 μ is so slow that any sizable cloud would require years to dissipate. However, clearing can occur in a very few days. This suggests the second or the third possibility, since for either alternative an evaporation, caused by atmospheric warming, could explain the rapid clearing. Recent unpublished calculations by the author indicate, for a convective mechanism of formation, that a CO_2 ice cloud would be far too opaque, but that an H_2O ice cloud could have proper optical and geometric thicknesses provided the surface frost point is near -90° C.

There is therefore some reason to believe that the haze is composed of tiny ice crystals.

The general circulation of Mars is a matter of potentially great interest to terrestrial meteorologists. There are surely no oceans on arid Mars, thus the complex interplay of continents and ocean apparent in our atmosphere is absent. There is some reason to believe that the orographic relief on Mars is appreciably less than our own. Finally, the relatively infrequent appearance of visible clouds means that incoming and outgoing radiation proceed in a far more regular way than on the earth. All these factors suggest that the Martian circulation may be a simpler and steadier one than our own.

The only way to study the general circulation of another planet is to observe the drift of its clouds. This, unfortunately, is difficult in the case of Mars because the few visible clouds that do appear seldom last sufficiently long to exhibit a measurable displacement. Several years ago I attempted to gather from the literature as many records as possible of clouds observed on two or more successive nights (Hess, 1950). When the eighteen wind drifts that were found were plotted on a map, it was discovered that they permitted an analysis that strongly resembled the earth's circulation. Thus there was evidence of subtropical high-pressure cells, middle latitude westerlies, and sharp cyclonic shears that may be due to frontal systems.

The paucity of these data, among other things, renders this attempt to delineate the circulation a preliminary one at best. During the close opposition of 1956 a concerted effort was made to gather much more material of this sort. Under the auspices of the International Mars Committee (a loose organization of scientists set up to promote and coordinate studies of Mars), a world-wide Martian cloud patrol was instituted. The observers were professional and skilled amateur astronomers distributed over the world. Each was asked to record the position and appearance of every cloud he could detect on the planet. To have many cooperating observers obviously permits a measure of independence of the limitations placed on telescopic observations by the vagaries of cloudiness and optical steadiness of our own atmosphere. However, the near equality of the axial rotation periods of the earth and Mars imposes just as serious a limitation. A single terrestrial observer sees nearly the same Martian longitude night after night, and it takes about a month for him to obtain observations of all of the planet. Only a global network of observers can overcome this restriction. The data collected during this unprecedented effort are now being gathered and collated by the author. There seems to be real hope that this program will lead to a significant increase in our knowledge of the general circulation of the planet Mars.

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DIVISION OF MYCOLOGY

SOME CONTRIBUTIONS OF THE HISTOPATHOLOGICAL METHOD TO THE STUDY OF FUNGUS DISEASES*

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During the past decade we have witnessed a remarkable upsurge of interest in fungi and the diseases they produce in man and animals. While formerly only a few dermatologists and a rare pathologist shared the botanist's interest in this subject, now the mycoses are discussed at meetings of surgeons, internists, pediatricians, ophthalmologists, veterinarians, and epidemiologists.

There are many reasons for this mounting interest; not the least important of these is the great improvement in techniques for the diagnosis of mycotic infection by culture, animal inoculation, histopathological and serological methods, and skin testing. Since my interest in the mycoses was enhanced greatly by technical advances and because most of my experience has been derived from histopathological studies, I shall confine my discussion to a review of some contributions of the histopathological method to medical mycology. I shall make little effort to compare the relative merits of this method with those of the others, for I do not believe that these techniques should be looked upon as competitive, but rather as complementary and supplementary. There are situations in which the histopathological method will provide answers that cannot be obtained otherwise, and it is to such contributions that I shall devote most of my time.

Advances in Special Staining Techniques

The present era of intensified interest in the histopathological demonstration of fungi began ten years ago with Ralph Lillie's extensive studies[1] at the National Institutes of Health, Bethesda, Md. Using the Bauer,[2] Feulgen,[3] Gram, and Gram-Weigert methods for the histopathological study of protozoa, bacteria, fungi, and metazoa, Lillie made significant observations and called attention to the special value of the Bauer stain** in the detection of small numbers of fungi in tissues. Re-

*This paper, illustrated with lantern slides, was presented at a meeting of the Division of Mycology on January 25, 1957.

** Several of the methods designated by eponyms and referred to in this paper as "stains" are not stains in the usual sense, but rather histochemical reactions; these include the Bauer, Feulgen, Gomori, Gridley, and Hotchkiss-McManus techniques. For a discussion of the chemical reactions involved, the interested reader is referred to pertinent references listed in the bibliography.

sults in the study of histoplasmosis with the Bauer stain were striking. *Histoplasma capsulatum* appeared as fine red purplish rings surrounding a clear zone about the centrally placed blue or pale blue nucleus. Organisms were found more readily with the Bauer stain than with azure-eosin or Giemsa stains. After digestion with saliva, ptyalin, and diastase, the Bauer-positive rings remained. Lillie made the important observation that *Histoplasma* could be found with the Bauer stain in lesions in which they were not stained by azure-eosin. These organisms had no nuclei and presumably were dead. This was the first indication that a method was available for the demonstration of nonviable fungi that had lost their stainability by ordinary techniques!

Lillie reported the Bauer stain to be effective also for the demonstration of species of *Candida, Cryptococcus, Coccidioides, Blastomyces, Penicillium,* and *Aspergillus.* This stain revealed structural details in the mycelial fungi that were not apparent with other staining methods. In the case of *Actinomyces,* however, the mycelial threads were not satisfactorily demonstrated by the Bauer stain; for actinomycetes the Gram-acetone and the Gram-Weigert methods, especially the latter, yielded the best results.

Pathologists in the Washington area were quick to learn of Lillie's results, even before they were published, and it was natural that the Bauer method should be given a thorough trial in the laboratories of the Armed Forces Institute of Pathology (AFIP). Lillie's observations were confirmed and extended and the Bauer was added to the list of "routine stains" of established value.

Subsequently, the periodic acid-Schiff reaction (PAS stain) advocated by McManus,[4,5] Lillie,[6] and Hotchkiss[7] as a method for histochemical study, was reported by Kligman, Mescon, and De Lamater[8] to be a useful method for demonstrating fungi in tissue sections and in smears. Their comparative studies convinced them that the PAS stain was superior to the Bauer in every instance.

The Bauer method employs chromic acid as an oxidizing agent to convert carbohydrates containing the 1,2 glycol groupings into aldehydes and the Schiff reagent as a stain for the reactive groups. In the Hotchkiss-McManus method,[8] periodic acid is used as the oxidizing agent. This liberates reactive groups in the host tissues and, as a consequence, the Schiff reagent stains many tissue elements along with the fungi. Kligman and his associates counterstained with light green in an effort to overcome this disadvantage.

During 1952 a modification of Bauer's technique that greatly increases the contrast between fungi and tissue elements was developed by the late Mary Francis Gridley.[9] She used Coleman's leuco-fuchsin as a Schiff reagent, and added Gomori's aldehyde-fuchsin stain[10] for elastic tissue because it increases the staining of hyphae. Gridley chose metanil

yellow for her counterstain since it provides such a pleasantly contrasting background.

The intensity with which the fungi are stained and the sharp contrast afforded by the uniform pale yellow background made this the stain of choice for screening purposes until Grocott[11] called attention to the use of Gomori's methenamine-silver technique (GMS stain).[12] This stain has been given an extensive trial in our laboratories, and we consider it unsurpassed for screening purposes. The method is similar to Bauer's except that methenamine-silver is used in lieu of Schiff's reagent. Grocott advocated this method mainly because it gave more photogenic results and because it utilized stable solutions that are readily available. Our considerable experience with the GMS stain not only has confirmed Grocott's claims, but also has convinced us that this is the most sensitive and useful of the special "fungus stains" developed to date. Fungi can be found more rapidly and under lower magnification than with other staining methods. Occasionally, fungi can be demonstrated with the GMS technique when they cannot be found in Bauer, Hotchkiss-McManus, or Gridley preparations. A striking example may be cited in the two cases of laboratory-acquired pulmonary histoplasmosis reported by Spicknall *et al.*[13] As the authors indicated, pathological studies failed to demonstrate the fungus despite the fact that several special stains were employed. Subsequently when the GMS technique was introduced and tried in these cases, pathologists at the AFIP were able to demonstrate the presence of *Histoplasma*.

Still another advantage of the GMS stain is its broader selectivity. In addition to the yeasts, yeast-like fungi, and higher mycelial fungi that can be well demonstrated by all the so-called fungus stains, GMS will often stain organisms that ordinarily are not visible in sections stained by the Bauer, PAS, or Gridley methods (for example, actinomycetes, tubercle bacilli, and other bacteria). Species of *Actinomyces* and *Nocardia*, however, are demonstrated much more reliably by one of the several techniques available for the Gram stain. The histopathologist can increase his percentage of correct etiological diagnoses of inflammatory lesions greatly by employing a battery of four stains: hematoxylin-eosin, Gomori's methenamine-silver nitrate, a Gram stain, and an acid-fast stain.

One additional special stain deserves brief mention, for it has helped us many times in the differential diagnosis of cryptococcosis. *Cryptococcus neoformans* is the only pathogenic fungus that produces a true mucinous capsule both *in vitro* and *in vivo*. Special stains for mucin or acid mucopolysaccharides[14] will demonstrate abundant mucinous secretion encapsulating the yeast cell. Color plates illustrating this unique property have been published recently.[15] Since no other yeast-like fungus possesses a mucoid capsule, these special stains help differentiate *C.*

neoformans from *H. capsulatum, Blastomyces dermatitidis, Candida* sp., and other fungi with which it may be confused.

Dividends Accruing from Technical Advances

Now I should like to discuss some of the progress made possible by extensive application of special staining procedures. First and most obvious are the ramifications of improved etiological diagnosis; second are the revisions of several old concepts that are now known to be inaccurate; and third are some epidemiological and endemiological data made available by the histopathological method.

Improved Etiological Diagnosis

Psychological and technical factors. One of the outstanding contributions of the new and highly sensitive staining techniques is psychological. For years the pathologist maintained a defeatist attitude toward etiological diagnosis. What was the use of spending valuable time looking for organisms that experience indicated could not be found? The pathologist now has weapons that bolster his confidence and make him eager for the battle of etiological diagnosis. The most potent of these is the Gomori methenamine-silver stain. Its sensitivity, coupled with the sharp contrast it provides between organisms and background, often makes it possible to detect fungi by scanning with the low-power objective. Another important psychological factor is the increasing awareness that tuberculosis and syphilis are not the only causes of granulomatous inflammation. Until recently it has been common practice in many laboratories to stain only for acid-fast bacilli in the study of granulomatous lesions. My first point, then, is that for psychological as well as technical reasons, the newer staining procedures enable the histopathologist to establish an etiological diagnosis in many more cases of fungus disease than before.

Multiple infections. My second point is an elaboration of the first. The psychological and technical factors that have increased the frequency of etiological diagnosis have also made possible the demonstration of multiple infectious agents, not only in different organs of a given patient, but within the same histological preparation. We have published, for example, photomicrographs of *Histoplasma, Cryptococcus,* and Reed-Sternberg giant cells of Hodgkin's disease, all found within a few millimeters of each other in one block of tissue*.

The character of the tissue response often provides a clue that leads to a demonstration of multiple organisms. A good example may be cited in the case of a patient with granulocytic leukemia who died of disseminated cryptococcosis**. Examination of various tissues obtained at autopsy revealed abscesses in the lung and lymph nodes. These were

*AFIP Acc. No. 278251 reported by Zimmerman and Rappaport.[16]
**AFIP Acc. No. 549631 previously recorded by Zimmerman and Rappaport.[16]

unlike the cryptococcal lesions and they did not contain fungi demonstrable by the hematoxylin-eosin, Gridley fungus, or periodic acid-Schiff stains. Gram stains, however, revealed a diffuse growth of delicate branching filamentous fungi interpreted as a nonacid-fast species of *Nocardia*.

Another example of how tissue reactions may vary with the organism responsible was obtained recently from the Children's Hospital in Washington, D.C. Lung biopsy led to the histopathological diagnosis of blastomycosis. However, when the lungs removed at autopsy were studied histologically, two granulomatous processes of completely different type were seen side by side. One was a diffuse process with many giant cells containing the *Blastomyces*. Adjacent was a larger spheroidal, sharply outlined granuloma of the type that is often called a "tuberculoma." Study of sections of this lesion stained by the Gomori technique revealed myriad *Histoplasma* at its center. Scattered discrete tubercles of the same type, also containing abundant *Histoplasma*, were found in other sections of lung and in the hilar lymph nodes.

Microbiological versus histopathological diagnosis. There are several reasons why thorough histopathological examination can provide information not obtainable by culture: (1) saprophytes or contaminants in cultures may overgrow the pathogen; (2) at autopsy fewer tissues are cultured than are examined histologically; (3) one fungus may be cultured, but a different one seen microscopically; or (4) two fungi may be found when only one was cultured. However, the discrepancy most often noted is the presence of histologically demonstrable fungi in lesions that were proved sterile by culture and animal inoculation. Particularly in the "tuberculoma type" of pulmonary granuloma (see below under *Etiology of "tuberculomas"*) consistent difficulty has been experienced in isolating any species of microorganism. Puckett,[17,18] Zimmerman,[19,20] and others[21-25] have found that these lesions frequently contain *Histoplasma* that are rarely seen in hematoxylin-eosin stained sections. The special "fungus stains" are required for their demonstration. This fact, and also the consistently negative cultures, have led to the belief that the organisms are dead, a conclusion that parallels that of Lillie cited earlier.

Commensal versus pathogen. The isolation of certain fungi, especially species of *Candida* and *Aspergillus*, from excreta has always presented problems in clinical interpretation. Even when these fungi are recovered consistently from the sputum, urine, or feces, etiological significance often cannot be assigned to them. This is especially true when dealing with debilitated patients or those receiving one or more of the "broad spectrum antibiotics." Conversely, on many occasions we have had the opportunity to demonstrate unequivocally that these fungi, which ordinarily are only commensals or symbionts, do possess the ability to become invasive.[26] Not only may they produce superficial ulcers through-

out the alimentary and respiratory tracts, but they also may penetrate deeply into the tissues, enter the blood stream, and produce widespread lesions. Sometimes the pathologist can state whether, at a given site, the fungus is entering or leaving a blood vessel by noting its direction of growth and its pattern of dichotomous branching.

Degree of dissemination. Frequently extensive lesions are seen in one or several organs, and the other viscera seem to be spared. For example, in many autopsied cases of cryptococcosis, only the brain and meninges appear to be involved. If, however, a systematic search for fungi is carried out, using appropriate staining techniques, the examiner will often be surprised to find how widely disseminated the infection really is.[16] Single organisms or small clusters of three or four yeast cells are difficult to demonstrate without special stains although great numbers of such organisms may be present in the tissues.

Experimental infections. The use of special stains for fungi is a "must" in the histopathological evaluation of experimental infections, especially in experiments designed to alter the usual course of a particular infection. This fact was impressed upon me during the course of some histopathological examinations of tissues obtained from rabbits that had died after having been infected with *H. capsulatum* and treated with large doses of cortisone. In some animals I had the greatest difficulty in demonstrating the fungus in hematoxylin-eosin-stained sections even though the concentration of *H. capsulatum* was extremely heavy.

Revisions of Old Concepts

Etiology of "tuberculomas." An enigma was presented by the "tuberculoma." This lesion was generally accepted by clinicians, radiologists, and pathologists as due to infection with the tubercle bacillus, despite the lack of etiological proof and the negative tuberculin reaction of the patient in many cases. This diagnostic problem became especially disturbing to the pathologist after thoracic surgeons adopted resection of solitary lung lesions as a routine procedure.[19,20] Efforts to obtain a solution by cultures and animal inoculations were undertaken, but these also yielded negative results. Harrassed by his clinical confreres, Thomas F. Puckett, a pathologist at the Fitzsimons Army Hospital*, began an investigation that led to the histological demonstration of fungi, morphologically consistent with *H. capsulatum,* in 22 surgical specimens.[17] He was successful because he employed the PAS stain and then studied his preparations carefully by oil-immersion microscopy. Puckett's material and histological preparations were reviewed at the AFIP where his observations and interpretations were confirmed. Recent publications by other groups[22,23] have also confirmed this important work.

*A center for the medical and surgical treatment of tuberculosis, in Denver, Colo.

In an effort to ascertain the relative frequency with which *Histoplasma* could be found in otherwise typical "tuberculomas," 35 cases so diagnosed were studied at the AFIP to which they had been referred, mainly from widely scattered military and Veterans Administration hospitals.[19] In all cases additional sections were prepared and stained for acid-fast bacilli, as well as for fungi. Fungi interpreted as *Histoplasma* were demonstrable in 19, and *Coccidioides* in 3 others. Acid-fast bacilli consistent morphologically with *Mycobacterium tuberculosis* were present in 6 lesions. In 7 granulomas no organisms could be found.

Puckett continued his studies, and finally reported on 67 cases in which pulmonary lesions, hilar lymph nodes, or both had been resected and in which the diagnosis of histoplasmosis was established by histopathological studies.[18] It is of interest to note that, although he was able to obtain positive cultures for *H. capsulatum* in only 2 instances, the intracutaneous histoplasmin reaction was positive in 62 of 63 patients.

During the last few years S. H. Rosen, Chief of the Section on Pulmonary and Mediastinal Pathology at the AFIP, has had a large experience with localized pulmonary granulomas resected surgically. He has noted that while the contributing pathologist frequently recognizes the presence of *Coccidioides* in such lesions, he usually fails to identify *Histoplasma* (TABLE 1). An explanation for this is that *Coccidioides* are often demonstrable in routine hematoxylin-eosin-stained sections from lesions of this type, while *Histoplasma* can be visualized only when appropriate stains are used. Rosen's experience has also confirmed my belief that other fungi, such as *C. neoformans* and *B. dermatitidis*, are rarely responsible for pulmonary granulomas of the "tuberculoma-type."[24]

TABLE 1

FUNGI FOUND HISTOLOGICALLY IN 94 RESECTED PULMONARY GRANULOMAS (JANUARY 1955 THROUGH MARCH 1956)*

	Identification by contributor and by AFIP staff	*Identification by AFIP staff only*	*Total*
Coccidioides	41 cases	10 cases	51 cases
Histoplasma	9 cases	31 cases	40 cases
Cryptococcus	1 case	1 case	2 cases
Blastomyces	1 case	0 case	1 case
Totals	52 cases	42 cases	94 cases

*Unpublished data accumulated at AFIP by S. H. Rosen and T. A. Thorson.[24]

It is only fair to mention, however, that all pathologists have not been able to find *Histoplasma* so readily in the lung lesions. In a recent study of 50 pulmonary granulomas, 22 of which were of the "tuberculoma-type" and all of which were of undetermined etiology, Starr and his associates at the Mayo Clinic reported that the PAS stain demonstrated *Histoplasma* in only one case.[27]

Rarity and lethality of histoplasmosis. Until about 10 years ago histoplasmosis was regarded as a rare and almost invariably fatal disease. The diagnosis in most reported cases was based on autopsy studies. Of 71 cases collected from the world literature by Parsons and Zarafonetis[28] in 1945, only 4 concerned patients who were still alive at the time of reporting. In 1950 Hodgson, Weed, and Clagett[29] collected 123 reported cases of histoplasmosis; 90 of these were autopsied cases, and only 5 of 62 patients with pulmonary infections were still alive when their cases were reported. Experience at the Armed Forces Institute of Pathology prior to 1950 led to similar conclusions, for only one case of nonfatal localized histoplasmosis diagnosed by biopsy was on file. All other cases of histoplasmosis proved by histopathological examination had been autopsied.

Since the epidemiological studies of Christie and Peterson[30] and of Palmer[31] were reported in 1945, a changed concept of the incidence and prognosis of *Histoplasma* infection has gradually evolved.[32,33] Most of the evidence was indirect, based on radiological and immunological studies. In a few instances, however, it was possible to recover *H. capsulatum* from tissues, blood, or exudates of patients with nonfatal, nonprogressive infection.[27,34-38] Experience with spontaneous histoplasmosis in animals, especially dogs, in highly endemic areas such as Ohio[39] and Loudoun County, Va.,[40] furnished corroborative evidence that unapparent infections were frequent.

It remained for histopathological studies to provide the most abundant direct evidence that histoplasmosis is usually characterized anatomically by healed, partially calcified, focalized granulomas, rather than by the disseminated "cytomycosis," formerly thought to be the typical histological picture. Puckett's studies[17] provided the opening wedge. Others confirmed and extended his observations. Straub and Schwarz,[25] for instance, reported histologically proved but healed lesions of histoplasmosis in the lungs of 70 of 105 patients who died of other causes in Cincinnati, Ohio. Similar data could be presented for coccidioidomycosis and cryptococcosis, other mycoses once believed to be fatal more often than not.[15]

Morphology of fungi in tissue. Application of histochemical methods has enhanced our knowledge of the structure of fungi in tissue and has demonstrated considerable pleomorphism that had escaped the attention of most earlier workers. *H. capsulatum*, for example, has conventionally been described as a small, ovoid or crescentic, basophilic mass, 1 to 2 μ

in diameter, surrounded by a clear "capsule," the entire cell being 2 to 4 μ in diameter. However, Kligman and Baldridge have shown that the fungus really has no true capsule.[41] The halo, regarded by earlier workers as a capsule and accounting for the name assigned to the species, is nothing more than an artifact produced by retraction of the cytoplasm from the cell wall together with the failure of the cell wall to stain when routine techniques are used.

The impression that such fungi as *H. capsulatum*, *C. immitis*, and *C. neoformans* show little or no pleomorphism and never produce mycelial structures in tissue was so firmly established as to constitute pedagogical dogma. Although these tenets were generally useful, they sometimes proved misleading; now we know them to be obsolete. Recently attention has been called to diagnostic difficulties encountered as a result of this newly recognized "pleomorphism" of *Histoplasma*.[21,42] In many of these cases, special "fungus stains" are required to reveal the pleomorphism and to demonstrate the formation of germ tubes and hyphae.

Morris Moore recently described a case of mycotic endocarditis which in 1939 was thought to be due to a species of *Candida;* but 15 years later on application of the newer techniques, it was shown to be a manifestation of histoplasmosis.[42] I have had a similar experience. In a 1950 paper[43] reporting 3 cases of mycotic endocarditis, I included one* in which the fungus was extremely pleomorphic and difficult to visualize, but which I interpreted as an *Aspergillus*. Subsequent study in the light of acquired experience and with the aid of periodic acid-Schiff and Gridley fungus stains led me to the conclusion that this was a case of *Histoplasma* endocarditis. It was included as such in Binford's 1955 paper[21] dealing with morphological variations of *H. capsulatum*.

Until recently it was generally agreed that the formation of hyphae by *C. immitis* in tissue was exceedingly rare. Forbus and Bestebreurtje[44] described this phenomenon for the first time in 1946 in a histopathological review of 95 cases of coccidioidomycosis. In one case hyphae were found in a cavitary lesion of the lung. Photomicrographs of mycelial forms in pulmonary lesions of coccidioidomycosis were published subsequently by several investigators.[45-47] Mahon[48] and Puckett,[46] at the Fitzsimons Army Hospital, found mycelial growth in many focalized and stabilized lesions of coccidioidomycosis. Using the periodic acid-Schiff stain and studying multiple blocks when necessary, Puckett was able to report that hyphae were present in 73 per cent of coccidioidal cavities and in 30 per cent of granulomatous lesions.[46] Pathologists at the AFIP have confirmed these observations repeatedly. This old dictum that *C. immitis* never forms hyphae in tissue still seems to apply in the case of progressive and disseminated coccidioidal infections.

Another observation seldom described in the past, but which we are

*AFIP Acc. No. 204556

making more frequently, is that fruiting bodies may be produced in tissue by species of *Aspergillus*. This phenomenon is usually encountered when the fungus is growing actively on the surface of a tissue – for example, the skin, the mucosa of the gastrointestinal tract, or the lining of a pulmonary cavity.

Paucity of tissue reaction to C. neoformans *and* H. capsulatum. The lack of suppuration or granulomatous inflammation has often been so impressive in cryptococcal meningoencephalitis and in disseminated histoplasmosis that pathologists have failed to realize that, especially, in focalized lesions, *C. neoformans* and *H. capsulatum* may stimulate the proliferation of exuberant granulation tissue or a frankly granulomatous process with many epithelioid cells and giant cells of the Langhans or foreign body type. Rarely these fungi may be found within lesions that are otherwise typical of sarcoidosis. Abscess formation may also be encountered. Here again, application of special staining techniques has established etiological diagnoses and has alerted pathologists to anticipate diagnostic possibilities in the course of examination of routine surgical and autopsy material.

Acquisition of Epidemiological and Endemiological Data

Confirmation of conclusions based on circumstantial evidence. I wish to emphasize here that while results of mass radiological and immunological surveys, interpreted in the light of knowledge gained from soil and animal mycology, provided the all-important data necessary for our present concept, it has been only on rare occasions that direct corroborative evidence has been obtained, as, for example, the histoplasmosis outbreak in the farm family described by Loosli *et al.*[36] With Puckett's demonstration of *Histoplasma* in old, healed, partially calcified lesions in the lungs and hilar lymph nodes[17] and the subsequent confirmatory reports of many other investigators,[19,22-25] ample direct evidence has accumulated. This has been one of the most auspicious benefits resulting from increased use of special staining techniques for fungi.

Provision of historical and epidemiological data. One of the distinctive advantages of the histopathological method is that old material can be restudied with new techniques as they become available. Surgical and autopsy specimens previously collected from other geographical areas can be compared with current material from our own country. A striking example of how valuable this approach can be was brought to my attention quite by chance. In 1953, while I was reviewing Puckett's cases of arrested histoplasmosis, I came across a similar healed lesion of the lung removed during the autopsy of a 4-year-old Panamanian child who had died of malaria at the Colón Hospital, Colón, Panama, in 1931. It will be recalled that Darling's[49-51] original cases of histoplasmosis were

from Panama, but thereafter the disease seemed mysteriously to have disappeared from that country until 1945, when a canine infection was reported.[52] It was found subsequently that a high incidence of skin reactivity to histoplasmin existed in the native population of Panama, and then 3 cases of disseminated histoplasmosis were reported from Panama between 1951 and 1954.[53] But what had happened between 1906 and 1945? Had histoplasmosis really disappeared from Panama? Did the focalized pulmonary nodule removed from the child who died of malaria hold the important answer? The answer was that it did. Special stains for fungi revealed myriad typical *Histoplasma,* identical with those demonstrated in Puckett's patients. Thus, the histopathological method gave information that supplied the missing link in the history of histoplasmosis in Panama.[53]

Study of animal infections. The histopathological method has been used to good advantage in conjunction with mycological techniques in epidemiological studies involving wild and domestic animals. That histopathological methods elicit evidence unobtainable by other methods is shown in Emmons and Ashburn's report on histoplasmosis in wild rats. They found typical lesions in some animals in which cultures had been negative.[54] Hence they suspected that the actual incidence of infection was greater than indicated by their mycological studies. Negative information that is acquired may also be significant. Rowley and his coworkers reported the isolation of *H. capsulatum* from 22 of 50 adult cats obtained in Loudoun County, Va., but these animals presented none of the characteristic gross or microscopic alterations of histoplasmosis, and the fungus could not be demonstrated histologically in a single case.[55] In dogs from the same county, however, they found discrete pulmonary lesions resembling those of human histoplasmosis, although the incidence of positive cultures in dogs was exactly the same as in cats (22 out of 50). In addition, the fungus was demonstrable histologically in 8 dogs.[55]

Summary

Pathologists have shared with others the mounting interest in diseases caused by fungi. The development of convenient, highly sensitive special staining techniques during the past decade has enabled pathologists to render more accurate diagnoses in the course of their routine study of autopsy and surgical specimens. The histopathological method has also played an important role in the revision of certain concepts which we had previously accepted, and it has contributed to the acquisition of epidemiological and endemiological data.

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associates at the Armed Forces Institute of Pathology, particularly C. H. Binford and S. H. Rosen, who for several years have shared with me their most interesting cases of mycotic infection, and to many others in the Washington area who have shown me their rare or diagnostically difficult cases.

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SECTION OF ANTHROPOLOGY

STUDIES IN FAMILY ORGANIZATION IN THE FRENCH CARIBBEAN*

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This is a preliminary report on a new research undertaking to study the social organization and cultural history of the rural population of the French Caribbean, sponsored by the Research and Training Program for the Study of Man in the Tropics**.

The work was undertaken to define and understand the French dimension in Caribbean social organization, once a very significant European dimension and influence† but reduced today to Martinique, Guadeloupe, and a few other smaller islands.[1,2] Such a statement implies that there are features of social organization that the research team assumed were pan-Caribbean, despite the obvious differences engendered by specific historic and cultural circumstances, such as the identity of the European power controlling the given territory. In our view the assumed common cultural background was the result of common experience with slavery and the sugar plantation as the dominant institutions before emancipation, and the subsequent emergence of a peasantry that abandoned the estates and settled with varying degrees of success in the highlands to practice subsistence agriculture. This culture historical model would apply primarily to Jamaica, Haiti, Guadeloupe, and Martinique, where the plantation developed early and reached its peak in the 18th century, and where slaves of African origin formed the bulk of the population; it would not apply to areas such as Cuba and Puerto Rico, where the plantation flourished later and the majority of the population in 1800 was of European descent.

Our interest in the presumed common social organizational background does not imply neglect of the idea that the major uniformizing force in this culture area has been the African heritage, the importance of which has been documented by Jean Price-Mars, Melville J. Herskovits, Fernando Ortiz, and the Bascoms.[3-13] The influence of this social organizational background, which is so noticeable in music and language, religious cults, and mortuary customs, has also been suggested, but less

*This paper was presented at a meeting of the Section on January 28, 1957.

**The author is grateful to the Program and to its research director, Vera Rubin, for the opportunity to participate in this study. He was accompanied in the field by three graduate students from Columbia University, New York, N. Y., one from Harvard University, Cambridge, Mass., and a Vassar College Undergraduate, and by Guy Dubreuil, instructor in anthropology at the Université de Montréal, Montreal, P. Q., Canada.

†The independence of Haiti and the loss of such territories with French Creole-speaking populations as St. Lucia and Dominica to the British provide us with interesting comparative levels within this French tradition. These levels cannot be discussed in detail here, but they will be a necessary part of any future systematic and comparative study of the Caribbean.

convincingly, for forms of family organization.[5,14-17] Our research is concerned with the African heritage; Africans continued to arrive in the French Caribbean long after the emancipation of 1848. As late as 1910 the census enumerated persons born in Africa; African surnames can occasionally be encountered in the Martinican countryside, and such place names as Fonds Congo and Morne l'Afrique can be located on the map. In the future we plan, therefore, to investigate the nature and significance of this heritage in our area.

And yet, since one of our major interests is the analysis of contemporary social systems in the Caribbean context, we feel that the concern with Eurafrican syncretisms must be matched with field studies of prevailing and functioning institutions, such as the independent peasant village, as well as plantation barracks and settlements. Such an emphasis parallels the interests of our colleagues at the main Caribbean research center, the Institute of Social and Economic Research at the University College of the West Indies in Jamaica; it stems from the fact that we do not think that social structure is an aspect of culture capable of diffusion as are motor habits or musical rhythms.[18] Institutional forms are much more likely to arise as responses to structural demands and these require protracted investigation and definition in the field, as well as familiarity with the area's ethnohistory.

For the first summer's work our group selected family organization as the focus of the inquiry. While each student and the writer conducted studies in separate villages, nevertheless it was felt that a common research interest was an asset for both the training aspect of the project and a test of the hypothesis that a common social organizational background including the French islands and other parts of the Caribbean was a reality.

Family organization in this area has been abundantly studied in the last twenty years. The study began in Haiti, where Price-Mars, followed later by Herskovits and Simpson,[19] has given us descriptions that provide interesting parallels for our own studies, since Haiti, Guadeloupe, and Martinique once shared the effects of the same colonial policy and a common administration. In later years, and particularly since the second World War, a prodigious amount of material on family organization in the British islands has been accumulated. At first, the primary concern was one of welfare; so many of the rural and slum urban households were found to be matrifocal with husbands and fathers in marginal roles, if not entirely absent, that the "Caribbean family" was described in terms of "disorganization" and "malfunction" and contrasted with the "Christian" family, based on legal marriage and other European and status considerations.[20,21] In recent years, a growing methodological sophistication has resulted in studies which avoid using European standards of normative family forms and concentrate on functional analyses of the existing structural relationships, all with excellent results.[18,22]

What literature on Martinican rural families was available indicated that their organization did correspond with general patterns found elsewhere in the Caribbean;[23-25] it also indicated differences from the French metropolitan *foyer* as described by Rhoda Metraux and her associates.[26] Some of these indications were: (1) wide prevalence in the French Caribbean of matrifocal families with correspondingly marginal roles for husbands and fathers; (2) comparatively low percentages of children defined by European law as "legitimate," taken by some observers as an indicator of a low percentage of "legal" marriages; (3) relatively large numbers of children per household, a condition viewed with mixed pride and resignation by the families; and (4) relatively easy adoption of infants, children, and even adults, in striking contrast to the reluctance prevalent in metropolitan France.[26]

Familiarity with the published sources indicated also that these features of household organization existed despite wide acquaintance of the Martinican rural population with French legal and Roman Catholic religious standards and family norms. These are insistently emphasized in the public schools with their unchanged European curriculum, through the efforts of the predominantly European clergy, and by the example of the educated middle classes. Although much, if not most, of the rural and urban slum population accepts these normative patterns as "good" and even preferable to its own practice, nevertheless, given Caribbean and Martinican realities, these norms cannot be functionally operative.

In addition to such hints from the literature, the French Caribbean training and research party made some other assumptions about family organization for which there was little or no confirmation in the published reports.* At a preliminary meeting at Vassar College, in the spring of 1956, the research party formulated its ideas as follows:

(1) In the study of Caribbean family forms, it is frequently misleading to assume that one knows a priori how to define or recognize what a family is, what constitutes a marriage, and which are the effective kinship bonds. All these must be identified and their functions ascertained in given circumstances, independent of European normative patterns.

(2) The most useful conceptual and functional unit in the study of Caribbean family organization is the household, which has proved its utility in comparable studies in British Guiana and Jamaica.[18,22] This allows us to understand the strength of consanguineal as opposed to affinal relations in a society where the lineage system is absent; it also permits us to disentangle forms of the family unfamiliar to the European eye, such as those in which each spouse remains a member of her or his parental household.

(3) The household must be seen not at any given moment in time alone, but as an ongoing institution with a developmental life cycle. One must

*There is unfortunately no French Caribbean research institution comparable to the Centro de Investigaciones Sociales at the University of Puerto Rico, San Juan, Puerto Rico, or the above-mentioned Institute of Social and Economic Research in Jamaica, B.W.I.

beware of mistaking a temporary form, such as "faithful concubinage" in the Simey vocabulary,[20] for the complete cycle of conjugal relations, since many couples throughout the Caribbean postpone the expensive and status-giving European ceremonies until late middle age*.

(4) Finally, we assumed that significant differences in the forms of family organization will be found between various regions of even such small and compact territories as Guadeloupe and Martinique. Previous research in Puerto Rico and Jamaica had indicated that family and household forms differed considerably in response to distinct histories, ecologies, and structural imperatives.[27,28] The salient contrast was expected between those areas, usually in the highlands and away from sugar plantations, where an independent peasantry had emerged (with its own land, with opportunities for men to acquire managerial skills and to play status-defining roles even within the framework of an essentially subsistence agriculture) and those regions where the prevalence of plantations meant seasonal work, dependent relationships, and consequent inadequate opportunities for men to assume responsibility for their households.

After a single summer's field work, it is, of course, too early to formulate any major conclusions either confirming or rejecting these hypotheses. The ten weeks that we spent in Martinique included a month-long preliminary survey of the island, five or six weeks of actual field work in a selected community, and a cursory visit to Guadeloupe by the field director. This is obviously an inadequate basis for confident statements. We were fortunate that two members of the team received additional grants that allowed them to remain in Martinique until the end of October**. In years to come two members of the group will be able to return for a year of field work, and the research will be extended to Guadeloupe.

Nevertheless, even in the short period of field work at our disposal, we were able to ascertain that family and household forms do tend to differ according to region. The interior highland belt beginning at Bezaudin and Morne des Esses and reaching south as far as La Renée in the upper reaches of Riviere Pilote, consists of a dense peasant population whose ancestors left the sugar *habitations* on the coast and went to rejoin the Maroon communities established in the hills before emancipation†. In numerous cases such settlements were organized by European

*Mariam Kreiselman, of Columbia University, who spent four months studying a Martinican plantation area in 1956, suggests that while most children born in her area were "illegitimate" their parents died in holy wedlock.

**Some of the results will be incorporated in a forthcoming doctoral dissertation by Mariam Kreiselman, submitted to Columbia University. Guy Dubreuil will return to Martinique in 1958.

†The extent and prevalence of such communities has not yet been the object of serious research. Some indication of their importance can be deduced from an article in the *Journal Officiel de la Martinique*, of 4 February, 1843, five years before emancipation, in which the anonymous author suggests the prohibition of all charcoal exports since "this industry is almost the only one that makes it possible for them to stay away from their master's estate... They use as intermediaries (in this commerce with charcoal) the blacks who have remained with their owners..." (my translation — JVM).

fathers for their Martinican offspring as indicated by the frequency of place names such as Rue Mulâtre and Fonds Gens Libres on the map. One is tempted to draw the analogy between such European-sponsored settlements and those organized by various British sects in the highlands of Jamaica.[29] In both cases the structure of the independent village is the same. Although capital and the original management came from Europe, the cultural forms taken by the settlement vary: in the British case, it is of a sectarian nature, while in the French islands it is the European father (and in at least one case, the European mother) who plays the propelling role. Similar interesting parallels between Haiti and the French Lesser Antilles are under study, particularly on the matter of continuity between Maroon settlements and postemancipation occupation by the peasantry.

The researches of Guy Dubreuil, confirmed in part by my own, indicate also that in such highland peasant communities where subsistence farming can be supplemented by such cash crops as bananas or by such crafts as tanning, basket weaving, or bus construction, and where the managerial and status functions of the men were very real, the families formed through status marriage frequently contracted quite early in the history of the household and sometimes before the birth of the first child. In such cases, the men were farmers who preferred to hold land in family properties,[28] to be subdivided only in the direst circumstances; siblings built huts next to each other in order to be able to exploit such family holdings; three-generation settlements, complete with father and grandfather-husbands, were not exceptional. Elsewhere, particularly in the plantation lowlands of Lamentin and Basse Pointe, where peasant holdings are few and dependence on the seasonal work on the plantation is the dominant fact of life, status marriage seems to be less frequent; the number of "unrecognized" as well as "illegitimate" children appears to be higher*. These conditions are reminiscent of those existing elsewhere in the Caribbean.

These conclusions are offered with some diffidence and without quantitative authority. We need much more field work of a protracted, detailed kind, with household censuses and qualitative, life-history materials for several areas, to indicate proportions, nuances, and the actual distributions of family forms. As indicated, it is regrettable that no sociological and culture historical institutions have arisen earlier in the French Caribbean**. Conditions at the insular and metropolitan level have been

*The *Code Civil* distinguishes three categories of children: "legitimate," those born of a status marriage or those legitimized by the subsequent marriage of their parents; "recognized" children, whose fathers have acknowledged their paternity before the authorities and who suffer no disability in inheritance or social status; and "unrecognized" children, whose fathers may be known, but who remain sociologically fatherless. Children in the latter category face social and economic disadvantages.

**In the 1920s Jules Monnerot published numerous documents dealing with the political and social structure of the 19th century in his *Revue Martiniquaise*. Material dealing with folklore has appeared in *Tropiques*, in *Revue de la Guadeloupe*, and in *Horizons Caraïbes*.[25,30] The *Annales des Antilles*, also published at Fort-de-France, specializes in 17th and 18th century history.

changing so rapidly since 1940 that the rural community is subject to considerable and very fundamental transformation. The increase in surviving children has led to grave pressure on family lands that are no longer adequate to permit the traditional subsistence allotment to each child. This leads to migration to the city and overseas; it also encourages the return to the plantation which some families had proudly rejected for three and four generations. Another factor promoting outside work for wages is the extension since 1948 of metropolitan social security benefits and family allowances to the islands*; self-employed persons, such as subsistence farmers and artisans, are not eligible for these payments. Migration and wage labor, as well as growing educational opportunities and contacts with metropolitan France, tend to blur the kind of differences in family and household organization that we have suggested. For this reason additional systematic research is urgently needed, with particular attention to the contrasts between Guadeloupe, its satellite islands and Martinique.

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*Since that date both Guadeloupe and Martinique have become departments of France, a virtually complete legal assimilation.

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THE INTERNATIONAL GEOPHYSICAL YEAR*

By Joseph Kaplan

United States National Committee for the International Geophysical Year, National Academy of Sciences, Washington, D. C.

About five thousand scientists and engineers throughout the world are preparing for the International Geophysical Year (IGY). Into the eighteen months of the IGY will be compressed a score or more of years of normal research as scientists attempt to achieve a unified picture of our physical environment. During the IGY scientists will explore almost every major land and sea area. They will study the earth's core and crust. They will probe into its interior with explosion sound waves and will launch rockets and satellites to explore the high atmosphere and outer space. They will measure the deep ocean currents and the surging tides in the seas. They will observe and measure the many mysterious particles that continually bombard the earth from outer space.

At the present time, fifty-five nations are formally participating in this endeavor: Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Bulgaria, Canada, Ceylon, Chile, The Chinese Peoples Republic, Colombia, Czechoslovakia, Denmark, Ecuador, Egypt, Ethiopia, Finland, France, Germany (West), Germany (East), Great Britain, Greece, Guatemala, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Mexico, Morocco, The Netherlands, New Zealand, Norway, Pakistan, Peru, The Philippines, Poland, Portugal, Rhodesia and Nyasaland, Rumania, Spain, Sweden, Switzerland, Tunisia, The Union of South Africa, The Union of Soviet Socialist Republics, The United States of America, Uruguay, Venezuela, and Yugoslavia.

The program of the United States has been planned by the nation's leading geophysicists, gathered together by the National Academy of Sciences. This program includes projects in the thirteen disciplines and areas of activity involved in the IGY: aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, the ionosphere, longitude and latitude determinations, meteorology, oceanography, seismology, solar activity, and rocket and satellite studies of the upper atmosphere. The program of the United States will include activity within the continental limits of the United States, Alaska, the Antarctic, the Equatorial Pacific, the waters of the Atlantic and Pacific, and various cooperative efforts with nations of North and South America.

With every advance in civilization, knowledge of weather patterns has grown increasingly important. One of the principal deficiencies in understanding weather and weather prediction has been the lack of adequate data from the southern hemisphere, particularly in the Antarctic and in

*This paper was presented at the Annual Dinner and Meeting of the Academy on December 6, 1956.

the vast oceanic regions surrounding it. During the IGY the United States will establish Antarctic stations at Little America, Marie Byrd Land, the South Pole, the Weddell Sea, Knox Coast, and a cooperative station with New Zealand at Cape Adare, in addition to an air facility at McMurdo Sound. These, combined with the other Antarctic stations and other United States and foreign stations in the southern hemisphere, will provide adequate meteorological coverage of that area for the first time in history.

In both the northern and southern hemispheres emphasis is being placed on meteorological measurements to heights of approximately 100,000 ft. An extensive chain of stations will launch balloon-borne weather instruments. These devices will radio back information on pressure, temperature, humidity, and winds. This information promises to reveal the true three-dimensional structure of the atmosphere, information which is needed for improved long-range weather prediction, as well as for an advance in our knowledge of basic weather patterns.

The Antarctic program will permit us for the first time to prepare daily weather maps of that huge continent. The Antarctic covers about six million square miles. Sheathed in ice and snow, this continent represents a unique region of cold weather which, it is suspected, exerts a major influence on the world's weather.

So little is known about the circulation of the deep ocean water that nobody knows whether it takes one hundred years or ten thousand for this water to travel from the Antarctic to the equator and back again. Why should we try to learn more about these deep ocean currents? There are several practical reasons. One is that the deep currents may be of great importance in long-range weather forecasting, particularly because of the exchange of water between the Antarctic and low latitudes. Second, the fertility of the ocean depends upon the exchange of water between the deeps and the surface; that is, the amounts of fish and other foods we can harvest from the ocean are finally limited by the rate at which the ocean overturns and thereby fertilizes itself. Third, the development of peaceful uses of atomic energy will probably result in the production of unbelievable quantities of radioactive substances, and somehow these must be disposed of safely. One possible thing to do with them is to dump them into the deep sea; the ocean's currents might spread them out to such an extent that they would be harmless. But we do not know whether this is a safe procedure because we do not know how fast the deep waters move or how they mix with the waters near the surface.

Many geophysical phenomena of fundamental importance occur in the high atmosphere of the earth. The fields of geomagnetism, aurora, ionospheric physics, and cosmic ray research are all directly related to events that occur at heights greater than fifty miles above the earth.

Over-all solar activity is measured by the eleven-year sunspot cycle.

Many other solar phenomena, such as enormous flares, prominences, and other types of regional activity vary according to the same time scale. As 1957-1958 will be a period of maximum solar activity, IGY scientists will develop detailed and comprehensive records in this field by means of systematic observations of the sun through improved and faster coordination of the observing programs of solar observatories. Solar activity will be observed both in the visible spectrum and at radio frequencies. In particular, solar flares will be studied and correlated with changes in cosmic rays, ionospheric and auroral disturbances, and geomagnetic phenomena.

During the IGY a spectroscopic observation program will give the distribution, both geographically and with respect to time during the auroral display, of radiations of the auroral spectrum. The visual and photographic observations of the aurora have as objectives the creation of synoptic maps showing auroral distribution at small intervals and the collection of data for statistical studies of aurora with other geophysical phenomena and with solar phenomena. With modern techniques such as the all-sky camera the IGY scientists will fill the gaps in knowledge about the aurora borealis in the Arctic, gather data heretofore unavailable about the aurora australis in the Antarctic, and trace the relationship between the two. Measurements of the intensity of airglow radiations will be made with photoelectric instruments of high sensitivity. The observing stations will be distributed along a longitudinal chain reaching from Arctic North America through Middle and Latin America to Antarctica.

Radio communications, affected by such solar activities as sunspots, sun-flares, and auroral displays, also suffer interference related to magnetic and ionospheric disturbances. On all of these phenomena cosmic rays exert an as yet incompletely ascertained influence. During the IGY scientists expect to gain knowledge of the reasons for the large decreases of cosmic ray intensity during some magnetic storms, for fluctuations in cosmic ray intensity near sunspot maximum, for the world-wide variation of cosmic ray intensity with the sunspot cycle, and for sudden large increases of cosmic ray intensity within an hour or less after the beginning of solar flares or chromospheric eruptions.

The United States-IGY geomagnetic program consists of a series of experiments designed mainly to yield facts about the rapid magnetic field fluctuations that are usually accompanied by disturbances in radio wave propagation and often by auroral displays, which also increase in number and intensity with an increase in the number of sunspots. To this end there will be a chain of geomagnetic stations stretching across the western United States in an east-west direction, another chain in Alaska in a north-south direction, and a third chain of four stations centered near the geomagnetic equator in South America.

The ionosphere is studied chiefly by means of the radio waves that

it reflects. IGY scientists will take vertical incidence soundings at a number of sites in the United States and oblique incidence soundings both in the United States and in the Pacific area. There will be measurements of sporadic-E back scatter by sweep and fixed frequency techniques, and experiments in forward scatter. Radio noise and ionospheric absorption will also be measured, and there will be an extensive network of stations to study whistlers.

One of the most important aspects of ionospheric research is that planned for the Antarctic. Soundings of the ionosphere have never before been made in this region, from which the sun is absent during the long winter months. Radiation from the sun is known to be the principal agent in breaking up the sparse atoms in the atmosphere at ionospheric heights to make possible the reflection of radio waves. During the long Antarctic night, however, particularly at the South Pole, the sun's radiation is absent. Scientists have no good explanation to account for the continued existence of ionized regions in the high atmosphere under these conditions, and they eagerly await the opportunity to study the composition and characteristics of the ionosphere in this unique situation.

Storms at sea and in the atmosphere are familiar enough. The earth itself appears solid and stable, but this is far from true. The earth is subject to continual stresses and strains, related in large measure to its varying composition. During the IGY three fields relating to the earth's crust and interior will be studied. Studies of seismology, which is concerned with earthquakes and similar events, will be conducted in remote regions. Measurements of gravity, the pull of the earth, will be made in areas where observations are now lacking – particularly in the Antarctic and in certain parts of the ocean. Determinations of latitude and longitude will be made at selected points, using both conventional astronomical techniques and a new photographic technique involving the moon.

Seismological studies have long been conducted on an internationally cooperative basis. The IGY gives scientists the opportunity to make additional measurements in remote areas, particularly at Antarctica and the equatorial Pacific islands. Virtually no measurements of this type have been made directly on the Antarctic continent. Seismographic instruments elsewhere in the world have shown that some of the largest earthquakes have occurred in the sub-Antarctic region, and earthquakes are occurring on that continent itself.

United States scientists will set up their instruments in the Atlantic and the Pacific, as well as on the North and South American continents and in Antarctica. They will record natural earth tremors and earthquakes; and they will make their own artificial tremors with dynamite charges in order to measure ice thickness in the Antarctic. The information obtained by the United States, combined with that procured through worldwide seismic studies conducted by other nations participating in the IGY,

will enable scientists to make a much better map of the interior of the earth than they now possess.

United States scientists will also attempt to measure linear strain directly with an instrument developed within the past few years by Hugo Benioff at the California Institute of Technology at Pasadena, Calif. There will also be projects to study the Lg. phase wave and long period seismic waves.

The fragmentary nature of knowledge of gravity over vast areas in the oceans, the Antarctic, and the Arctic renders suspect our conclusions about the shape of the earth as a whole. The United States plans a number of gravitational studies for the IGY. Gravimeter measurements are to be coordinated with the seismic exploration program and can be carried out by the same personnel.

The program of the United States in glaciology will encompass detailed studies at points in the northern hemisphere and at stations in the Antarctic, as well as reconnaissance observations in the western United States, Alaska, and portions of the Arctic in cooperation with Denmark and Canada.

Until recently, studies of the upper atmosphere have been seriously handicapped because direct observations and measurements were impossible. Conventional balloon techniques, such as those used in weather observations, do not extend beyond about twenty-four miles. Consequently, studies of the upper atmosphere have depended upon indirect measurements such as those made in probing the ionosphere.

The need for accurate information from the upper atmosphere calls for direct measurements, and these can be made only by sending instruments into the region under exploration. Rockets and satellites are devices that permit man to send his instruments into the high regions of the atmosphere.

Rockets have already been successfully used to study the outer atmosphere. Certain solar radiations, for example, that are absorbed by the atmosphere and hence never reach the earth's surface, have been investigated. A rocket measurement led to the discovery of solar X rays in one of the ionospheric layers. Measurements of ultraviolet radiation have established the variation in the height of the ozone in the atmosphere up to an altitude of forty-two miles. What are believed to be auroral particles have been detected by rocket-borne Geiger counters, and the density of charged particles in the ionosphere has been measured directly.

The importance of rocket measurements is threefold: first, they provide direct measurements of events in the high atmosphere; second, these direct measurements permit us to upgrade the indirect data collected more economically from many ground stations, greatly increasing their value; and third, they make possible new discoveries, such as that of X rays in the ionosphere.

A variety of investigations are included in the United States rocket program. Studies of the structure of the atmosphere will include measurements of pressure, temperature, density, and winds. Special instruments will be used to measure the atmosphere's chemical and ionic composition. Particles and radiations from the sun will be observed and measured, as will the nature of auroral particles. Variations in the composition of the ionosphere will provide information on the electrical currents flowing in the lower part of this layer.

We shall launch about two hundred rockets, including Aerobees that reach an altitude of about two hundred miles and Rockoons that travel perhaps sixty miles above the earth. Most of the Aerobees will be fired from Fort Churchill in cooperation with Canada, and some from White Sands and Alamogordo, New Mexico. Rockoons will be launched from shipboard in many areas, including waters off the Antarctic coastline, off the west coast of North America, in equatorial regions, and Arctic waters. This basic program will be supplemented by launchings of Nike Deacons, small rockets assembled as two-stage combinations, which are scheduled for release from both Fort Churchill and White Sands. The launching schedule of the United States rocket program is being closely coordinated with all other IGY studies, and special firings will be undertaken on days of unusual solar activity.

While rockets provide crucial information about the upper atmosphere, they have two limitations. First, the time of their total flight is extremely short, while the time spent in a particular altitude range is even shorter; and, second, rocket coverage is limited to a small part of the earth. Thus, in spite of the great value of rocket data, much of which can be obtained only by rockets, there is need for a tool that can provide data over a long period of time, over considerable heights above the earth, and over large expanses of the atmosphere about the earth.

A satellite can achieve these objectives, and for these reasons several international bodies strongly urged inclusion of satellites in the IGY effort. The satellite, in effect, represents an extension of rockets, which led me to call our satellite program the "LPR" – the long-playing rocket.

Interest in earth-circling research satellites for the IGY began during the summer and early fall of 1954, with the adoption of resolutions dealing with the desirability of such vehicles. These resolutions were adopted by three international scientific bodies: The International Scientific Radio Union, the International Union of Geodesy and Geophysics, and the Special Committee for IGY of the International Council of Scientific Unions (CSAGI).

In view of these international recommendations, the United States National Committee for the IGY (USNC-IGY) studied the possibility of constructing, launching, and observing an instrumented IGY satellite. These studies led to the conclusion that an instrumented satellite pro-

gram was not only of scientific importance, but was feasible. On March 14, 1955, accordingly, the committee transmitted its general recommendation for its IGY satellite program to the President of the National Academy of Sciences and to the Director of the National Science Foundation.

Within the United States, broad participation of American scientists in this endeavor is being effected by the National Academy of Sciences, which established the United States National Committee for the IGY. This committee, with its subcommittees and panels, is charged with responsibilities for planning, directing, and executing the United States-IGY effort, embracing every discipline and area of our IGY participation. The government has cooperated extensively in the realization of the program, both program-wise and fiscally.

In the development of the satellite program and assignment of responsibilities, the National Academy's committee recognized that there were two major areas of activity. First, there were the engineering problems associated with the design and construction of the propelling rocket vehicles, their launching, and associated logistics problems. Second, there were the problems of the scientific program, and here we had in mind, first, the radio and optical ground observation and measurement programs, and, second, the various experiments, both ground-based or contained within the satellite itself, which might most profitably be conducted in the interests of the IGY and science.

In recent years significant scientific studies of the upper atmosphere have been conducted by the civilian laboratories of the Department of Defense and their industrial and university contractors, using research sounding rockets. The experience and competence of these groups led the committee to request the government to utilize this talent in the design, construction, and launching of the rockets. This responsibility has been assigned to the Naval Research Laboratory, which is in charge of the contributions of the three military services and various industrial contractors.

Present plans call for the satellite to be launched from the east coast of Florida at Cape Canaveral. A three-stage rocket will be used to place it in its orbit. The rocket will be about 72 (22 m.) ft. long and will have a maximum width of 45 (115 cm.) in. It will be finless, using internal control for guidance.

The first stage will have a thrust of 27,000 (12,250 kg.) lbs. This will propel the system upward, gradually tilting, until at burnout the vehicle will be moving at an inclination of approximately 45°. The first stage will be discarded at burnout, and the second stage will take command.

The second stage will include the control systems for all three stages: guidance during the flight of the first two stages, guidance during the coasting of the second stage, and the start of the third stage.

The second-stage motor will drive the vehicle to an altitude of about

140 miles (225 km.) and then coast some 700 miles (1130 km.) to attain a desired altitude of between 250 and 300 miles (400 to 485 km.). At this altitude, after the nose cone has been ejected, the third and final stage will have begun. The second stage will be discarded and the third stage will quickly consume its solid fuel in impelling the satellite into its orbit with the necessary orbital velocity of 18,000 miles (28,900 km.) per hour.

The first satellite will be spherical in shape, about 20 in. (50.8 cm.) in diameter, and will weigh approximately 21.5 lb. (9.8 kg.). About half of this weight will be required for the instrument itself; the other half will be left for the various instruments, including the telemetering system.

The satellite's orbit will permit it to revolve about the earth in an apparent latitude range about 40° on either side of the equator. As it revolves about the earth once in slightly more than 1½ hrs., the earth will rotate beneath it. Since the earth rotates about its axis once every 24 hrs., it will have made about one sixteenth of a revolution each time the satellite orbits once completely. If the orbit of the satellite were circular, one sixteenth of a revolution, or 22.5°, would be approximately accurate. The orbit will be elliptical, however, so that more than one sixteenth of a revolution will be made by the earth during one revolution of the satellite: the displacement will be about 25°. Thus, after one revolution, the satellite will appear about 25° west of its launching site, 50° on its second passage, and so on.

In this orbit between 40° north to 40° south of the equator, the satellite's instruments will be able to record observations over an appreciably broad expanse of the high atmosphere. This 80° coverage will permit many scientists of a large number of nations to take measurements and to make observations. The United States National Committee (USNC) hopes that, after the initial ones, some satellites may be placed in other orbits so as to permit scientists of additional nations to participate in the study.

Once placed in its orbit, the satellite becomes in effect a celestial body. As such, the first problem becomes its acquisition – those initial observations which not only establish its celestial existence, but which provide data for preliminary calculations of its orbit in order that ephemerides may be made. These predictions will permit, first, the concentration of ground stations on the preliminary orbit, and, second, the subsequent acquisition of more extensive data on the basis of which the various studies can be conducted.

Precision in determination of the orbit of the satellite as it moves in its elliptical path from between 200 to 300 to perhaps 800 to 1500 miles (320 to 485 to 1300 to 2400 km.) from the earth is necessary, therefore, to the achievement of the planned experiments. Plans call for tracking, observation, and measurements made by using both optical and radio

methods. One of the difficulties in the initial optical acquisition of the satellite is the problem presented by atmospheric conditions. Extensive cloud cover, for example, would minimize the chance of optical acquisition. Here the radio system can play an important part.

Radio observations will employ a system developed by the Naval Research Laboratory. It is a precision, several-component system known as Minitrack. Ground stations using the Minitrack will include a precision multiple antenna array and an extensive electronics installation, requiring an operating staff of several technicians. The expected precision of observations is about 3 min. of arc under normal conditions, with improvement to a precision of 20 sec. of arc for observations at small zenith angles, or for nighttime operation. The USNC plans to install a limited number of stations with this type of equipment.

A second radio tracking system, called the Mark II Minitrack, is of lower precision, but still of great value because of its adaptability to extensive use. A broad network of such stations would contribute appreciably to the program, particularly in the acquisition and tracking of the satellite.

Optical observations of the satellite can be effected by three types of programs. The most precise optical observations will be made, using a modified Schmidt camera developed at the Smithsonian Astrophysical Observatory. Continuous-strip film will simplify the problem associated with following the satellite. To provide accurate timing, crystal clocks calibrated against WWV, the radio station operated by the federal government of the United States, will give a signal for photography simultaneously with the satellite. Time must be read to the millisecond. Before the Schmidt cameras can be employed, however, the path of the satellite must be known to a precision of about 3°.

Some of the photographic stations currently proposed are along the 75° meridian, as are most of the radio stations, while others extend east-west toward the northern end of the satellite's band width where visibility conditions appear more favorable.

The Schmidt camera system requires that the path of the satellite be known initially to a precision of 3° so that preliminary sighting positions can be established. The radio tracking system will provide this information but, to provide for the remote chance of radio failure in the satellite, a network of organized volunteer observers will be used.

Returning to the volunteer visual observers satellite program: although a particular individual will obviously have difficulty in viewing the satellite, trained teams of observers can undertake a satellite acquisition program. By placing binoculars on fixed mounts and employing a group of such installations disposed so as to cover a large region of the heavens, with good data as to position of the installation, timing of observations, and critical review of the observations by scientists, a major contribution to the over-all program is possible.

One of the most important sets of experiments in the earth satellite program, as I have suggested, relates to observations, measurements, and calculations that can be made from ground stations. Here both radio and optical observation stations play significant roles. The following are three areas of study that can be conducted:

(1) *Air density.* Very little is presently known about the density of the upper atmosphere. From the geometry of the satellite's course and observations of its flight, calculations can be made of the air density.

(2) *Composition of the earth's crust.* The satellite orbit will have a basic periodicity with perturbations dependent upon local nonuniformities in the gravitational field. Careful observations of the orbit and its variations will permit calculations of mass distribution in the earth. This, in turn, should yield information about the composition of the crust.

(3) *Geodetic determinations.* Determinations similar to those noted above will provide data about the oblateness of the earth. Synchronized observations may permit improvements in determinations of longitude and latitude. These observations would supplement the observations that are planned in the IGY longitude and latitude program.

In addition to the experiments described above, the satellite affords a unique tool for observing atmospheric and cosmic phenomena not directly susceptible to measurements on the earth, phenomena which in many instances are masked by the earth's atmosphere. It is expected, within the payload limitations of the satellite, that a number of research experiments on temperatures, pressures, meteoritic particles, ultraviolet radiation, and cosmic rays can be conducted.

The IGY satellite program is one part of the unprecedented cooperative international effort. However, the earth satellite is unique in one sense: all the other disciplines to be investigated during the IGY represent, in one form or another, extensions of existing work. They are unprecedented in scope and intensity; the results to be achieved may well extend man's knowledge of the physical universe immeasurably. The satellite program, on the other hand, is revolutionary. Nothing like it has ever been attempted before. Limited though it may be, it represents a great advance in terms of man's relationship to his cosmic environment. The fact that man can make a satellite and set it in an orbit about the earth is a milestone in man's continuing search for knowledge about his physical environment. Perhaps even more auspicious is the fact that men are taking this historic step jointly under the aegis of the IGY, an unprecedented, cooperative exploration of our physical environment.

CONFERENCES HELD

SECTION OF BIOLOGY

IMMUNOLOGY AND CANCER*

Friday, January 4 and
Saturday, January 5, 1957

Conference Chairman: Jerome T. Syverton
Department of Bacteriology and Immunology
University of Minnesota Medical School
Minneapolis, Minn.

FRIDAY, JANUARY 4, 1957

ANALYSIS OF CELLS

Session Chairman: Wendell Stanley
University of California, Berkeley, Calif.

9:00 A.M. –
Greetings from the Academy – A. S. Gordon, Chairman, Section of Biology, The New York Academy of Sciences, New York, N. Y.; New York University, New York, N. Y.

"Physical Methods for the Analysis of Cells" – Joseph W. Beard, Duke University School of Medicine, Durham, North Carolina.

"Chemical Methods for the Analysis of Cells" – Van R. Potter, University of Wisconsin School of Medicine, Madison, Wis.

"Cytochemical Approaches to the Analysis of Cells" – Arthur Pollister, Columbia University, New York, N. Y.

"Genetics of Transplantation" – George D. Snell, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine.

"Cytogenetic Aspects of Compatibility" – Theodore S. Hauschka, Roswell Park Memorial Institute, Buffalo, N. Y.

Open Discussion

*This conference was held in cooperation with the Allergy and Immunology Study Section and the National Cancer Institute of the National Institutes of Health, Public Health Service, Bethesda, Md.

IMMUNOLOGIC TECHNIQUES AND THEIR APPLICATIONS

Session Chairman: Michael Heidelberger
Institute of Microbiology, Rutgers University
New Brunswick, N. J.

2:00 P.M. –

"Quantitative Precipitation" – Otto J. Plescia, Institute of Microbiology, Rutgers University, New Brunswick, N. J.

"Agar-gel Diffusion and Immunoelectrophoretic Analysis" – Pierre Grabar, Institut Pasteur, Paris, France.

"Immunochemical Analysis Based on Complement Fixation" – Maurice Rapport, Sloan-Kettering Institute for Cancer Research, New York, N. Y.

"Virus Neutralization Tests, Implications and Interpretations" – Frank L. Horsfall, Jr., The Rockefeller Institute for Medical Research, New York, N. Y.

"Radiolabeled Antibodies" – David Pressman, Roswell Park Memorial Institute, Buffalo, N. Y.

"Purification of Tumor Localizing Antibodies" – Eugene Day and David Pressman, Roswell Park Memorial Institute, Buffalo, N. Y.

"Application of Fluorescent Antibodies to the Study of Naturally Occurring Antigens" – Albert Coons, Harvard Medical School, Boston, Mass.

"Diffusion Chamber Techniques for Studies of Cellular Immunity" – Glenn Algire, National Cancer Institute, National Institutes of Health, Bethesda, Md.

Open Discussion

SATURDAY, JANUARY 5, 1957

RESULTS OF IMMUNOLOGICAL TECHNIQUES

Session Chairman: Renato Dulbecco
California Institute of Technology, Pasadena, Calif.

9:00 A.M. –

"Tissue-Specific Antigens" – Ernest Witebsky, University of Buffalo School of Medicine, Buffalo, N. Y.

"Acquired Tolerance in Newborn Animals" – Leslie Brent, University College, London, England.

"The Distribution and Immunochemical Properties of Human Tissue and Tumor Antigens" – Leonard Korngold, Sloan-Kettering Institute for Cancer Research, New York, N. Y.

"Interpretation of Host Response in Quantitative Studies on Animal Viruses" – W. Ray Bryan, National Cancer Institute, National Institutes of Health, Bethesda, Md.

"Virus Neutralization" – Edward Eckert, State University of New York College of Medicine, Brooklyn, N. Y.

"Cell-Virus Relations in the Rous Sarcoma" – Harry Rubin, California Institute of Technology, Pasadena, Calif.

"Modification of the Immune Response by Radiation and Cortisone" – William Taliaferro, Department of Microbiology, University of Chicago, Chicago, Ill.

Open Discussion

HOST CELL RESPONSE

Session Chairman: Peyton Rous
The Rockefeller Institute for Medical Research
New York, N. Y.

2:00 P.M. –

"The Cytotoxic Effects of Antitumor Sera" – Robert W. Wissler and Martin H. Flax, Department of Pathology, University of Chicago, Chicago, Ill.

"Cytotoxins and Cytotoxic Antibodies" – John D. Ross, Department of Bacteriology and Immunology, University of Minnesota, Minneapolis, Minn.

"Cytotoxin Studies" – Karl Habel, Basic Studies Section, Laboratory of Infectious Diseases, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Bethesda, Md.

"The Nature of the Antigens in Transplantation Immunity" – Leslie Brent, University College, London, England.

"Acquired Tolerance Applied to Experimental Tumors" – Hilary Koprowski, Viral and Rickettsial Section, American Cyanamid Company, Lederle Laboratories Division, Pearl River, N. Y.

"Heterotransplantability of Tumors" – Harry S. N. Greene, Yale University Medical School, New Haven, Conn.

"Immunological Problems Associated with the Heterotransplantation of Human Tumors" – Helene W. Toolan, Sloan-Kettering Institute for Cancer Research, New York, N. Y.

SUMMARY OF CONFERENCE

Howard B. Andervont, National Cancer Institute
National Institutes of Health, Bethesda, Md.

Open Discussion

CELLULAR BIOLOGY, NUCLEIC ACIDS AND VIRUSES*

Monday, January 7, Tuesday, January 8, and Wednesday, January 9, 1957

MONDAY, JANUARY 7, 1957

POLIOMYELITIS

Session Chairman: J. ØRSKOV
State Serum Institute,
Copenhagen, Denmark

9:00 A.M.

Welcoming Remarks—Ross F. Nigrelli, President of The New York Academy of Sciences; New York Zoological Society, Zoological Park, The Aquarium, New York, N. Y.

"Mechanisms of Infection with Polioviruses"—David Bodian, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Md. (30 minutes)

Discussion:

Dorothy M. Horstmann, Yale University School of Medicine, New Haven, Conn. (10 minutes)

"Control of Poliomyelitis with a Noninfectious Vaccine"—Jonas Salk, Municipal Hospital, Pittsburgh, Pa. (30 minutes)

Discussion: (10 minutes each)

R. D. Defries, Connaught Medical Research Laboratories, University of Toronto, Toronto, Ont., Canada.

James H. S. Gear, South African Institute for Medical Research, Johannesburg, South Africa.

Alexander D. Langmuir, Epidemiology Branch, Communicable Disease Center, Atlanta, Ga.

*This conference was dedicated to and was held in honor of Basil O'Connor to celebrate his sixty-fifth birthday.

Herdis von Magnus, State Serum Institute, Copenhagen, Denmark.

Joseph E. Smadel, National Institutes of Health, Bethesda, Md.

"Facts and Perspectives of a Vaccine Field Trial"—Thomas Francis, Jr., School of Public Health, University of Michigan, Ann Arbor, Mich. (30 minutes)

Discussion: (10 minutes each)

William G. Cochran, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Md.

A. Bradford Hill, The London School of Hygiene and Tropical Medicine, London, England.

POLIOMYELITIS

Session Chairman: A. Bradford Hill
The London School of Hygiene and Tropical Medicine,
London, England

2:00 P.M.

"Properties of Attenuated Polioviruses and Their Behavior in Human Beings"—A. B. Sabin, The Children's Hospital Research Foundation, Cincinnati, Ohio. (30 minutes)

Discussion: (10 minutes each)

Hilary Koprowski, Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y.

G. W. A. Dick, Queen's University, Belfast, Northern Ireland.

Renato Dulbecco, California Institute of Technology, Pasadena, Cal.

R. E. Shope, The Rockefeller Institute for Medical Research, New York, N. Y.

"Immunization with Killed Poliovirus Followed by Induced Infection with Attenuated Poliovirus"—John R. Paul, Dorothy M. Horstmann, Joyce V. Deutsch, and Joseph L. Melnick, Yale University School of Medicine, New Haven, Conn. (20 minutes)

Discussion: (10 minutes each)

P. Lépine, Institut Pasteur, Paris, France.

C. H. Stuart-Harris, Royal Hospital, Sheffield, England.

John P. Fox, Tulane University School of Medicine, New Orleans, La.

"Physical and Chemical Characteristics of Purified Poliomyelitis Virus"—Carlton E. Schwerdt, University of California, Berkeley, Cal. (30 minutes)

Discussion: (10 minutes each)

Manfred Mayer, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Md.

Jesse Charney, Merck Institute for Therapeutic Research, West Point, Pa.

NUCLEIC ACIDS

Session Chairman: V. R. POTTER
The Medical School, University of Wisconsin,
Madison, Wis.

8:00 P.M.

"The Structure of the Nucleic Acids and Related Substances"—F. H. C. Crick, Cambridge University, Cambridge, England. (30 minutes)

Discussion: (10 minutes each)

M. H. F. Wilkins, King's College, London, England.

Alexander Rich, National Institutes of Health, Bethesda, Md.

"The Biosynthesis of Ribopolynucleotides"—Severo Ochoa, New York University-Bellevue Medical Center, New York, N. Y. (30 minutes)

Discussion: (10 minutes each)

Arthur Kornberg, Washington University School of Medicine, St. Louis, Mo.

John D. Smith, University of California, Berkeley, Cal.

TUESDAY, JANUARY 8, 1957

NUCLEIC ACIDS

Session Chairman: W. M. STANLEY
University of California,
Berkeley, Cal.

9:00 A.M.

"Electron Microscopic Studies of Tobacco Mosaic Virus and of Nucleic Acids"—Robley C. Williams, University of California, Berkeley, Cal. (30 minutes)

"The Infectivity of Tobacco Mosaic Virus Nucleic Acid"—H. L. Fraenkel-Conrat, University of California, Berkeley, Cal. (30 minutes)

Discussion: (10 minutes each)

George E. Palade, The Rockefeller Institute for Medical Research, New York, N. Y.

R. D. Hotchkiss, The Rockefeller Institute for Medical Research, New York, N. Y.

"Investigations on the Ribonucleic Acid of Tobacco Mosaic Virus"—Gerhard Schramm, Max-Planck Institute for Virus Research, Tübingen, Germany. (30 minutes)

"The Biological Activity of Tobacco Mosaic Virus Components"—Barry Commoner, Washington University, St. Louis, Mo. (30 minutes)

Discussion: (10 minutes each)

N. W. Pirie, Rothamsted Experimental Station, Harpenden, Herts, England.

F. C. Bawden, Rothamsted Experimental Station, Harpenden, Herts, England.

NUCLEIC ACIDS

Session Chairman: M. DEMEREC
Carnegie Institution of Washington,
Cold Spring Harbor, N. Y.

2:00 P.M.

"Experimental Problems Concerning the Role of Nucleic Acid in Growth of T_2"—A. D. Hershey, Carnegie Institution of Washington, Cold Spring Harbor, N. Y. (30 minutes)

Discussion: (10 minutes each)

André Lwoff, Institut Pasteur, Paris, France.

Max Delbrück, California Institute of Technology, Pasadena, Cal.

E. L. Tatum, The Rockefeller Institute for Medical Research, New York, N. Y.

Colin M. MacLeod, University of Pennsylvania School of Medicine, Philadelphia, Pa.

Seymour Cohen, University of Pennsylvania, Philadelphia, Pa.

"The Role of Nucleic Acid in Protein Synthesis, with Special Reference to the Cell Nucleus"—Alfred E. Mirsky, The Rockefeller Institute for Medical Research, New York, N. Y. (30 minutes)

Discussion: (10 minutes each)

Paul Zamecnik, Massachusetts General Hospital, Boston, Mass.

Fritz A. Lipmann, Massachusetts General Hospital, Boston, Mass.

"Possibilities of Metabolic Interferences with Nucleic Acids"—George B. Brown, Sloan-Kettering Institute for Cancer Research, New York, N. Y. (30 minutes)

Discussion: (10 minutes each)

Howard E. Skipper, Southern Research Institute, Birmingham, Ala.

John M. Buchanan, Massachusetts Institute of Technology, Cambridge, Mass.

WEDNESDAY, JANUARY 9, 1957

PROPERTIES ACQUIRED BY CELLS MAINTAINED IN CONTINUOUS CULTURE

Session Chairman: E. W. GOODPASTURE
Armed Forces Institute of Pathology,
Walter Reed Army Medical Center,
Washington, D. C.

9:00 A.M.

"The Mammalian Cell as an Independent Organism"—Theodore T. Puck, University of Colorado Medical Center, Denver, Colo. (25 minutes)

Discussion: (10 minutes each)

Harry Eagle, National Institutes of Health, Bethesda, Md.
André Lwoff, Institut Pasteur, Paris, France.

"Altered Cell Strains in Continuous Culture: A General Survey"—Raymond C. Parker, Connaught Medical Research Laboratories, University of Toronto, Toronto, Ont., Canada. (20 minutes)

"Indirect Evidence of Changes in Nutrient Requirements of Human Epithelial-like Cells in Continuous Culture"—R. S. Chang, Harvard University School of Public Health, Boston, Mass. (20 minutes)

"Tumor Formation by Cultured Cells Derived from Normal and Cancerous Individuals"—Alice E. Moore, Sloan-Kettering Institute for Cancer Research, New York, N. Y. (20 minutes)

"Comparative Studies of Normal and Malignant Cells in Continuous Culture"—Jerome T. Syverton, University of Minnesota, The School of Medicine, Minneapolis, Minn. (20 minutes)

"Criteria for Determining Malignancy in Tissue Culture Cell Lines in the Albino Rat"—Lewis L. Coriell, South Jersey Medical Research Foundation, Camden, N. J. (20 minutes)

Discussion: (10 minutes each)

Robert F. Parker, Western Reserve University, School of Medicine, Cleveland, Ohio.

Harry Eagle, National Institutes of Health, Bethesda, Md.

J. Leighton, University of Pittsburgh, School of Medicine, Pittsburgh, Pa.

H. S. Ginsberg, Western Reserve University, School of Medicine, Cleveland, Ohio.

Shields Warren, New England Deaconess Hospital, Boston, Mass.

ROLE OF TISSUE CULTURES IN THE ISOLATION AND STUDY OF VIRUSES

Session Chairman: JOHN R. PAUL
Yale University School of Medicine,
New Haven, Conn.

2:00 P.M.

"ECHO Viruses"—Joseph L. Melnick, Yale University School of Medicine, New Haven, Conn. (30 minutes)

Discussion: (10 minutes each)

A. J. Rhodes, Director, School of Hygiene, University of Toronto, Toronto, Ont., Canada.

H. A. Wenner, University of Kansas Medical Center, Kansas City, Kans.

D. T. Karzon, The University of Buffalo, Buffalo, N. Y.

G. J. Dalldorf, State of New York Department of Health, Albany, N. Y.

"The Significance of Adenoviruses as Agents of Respiratory and Ocular Diseases"—Robert J. Huebner, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Bethesda, Md. (30 minutes)

"Measures for Control of Adenovirus Diseases"—Maurice R. Hilleman, Walter Reed Army Institute of Research, Washington, D. C. (30 minutes)

Discussion: (10 minutes each)

H. S. Ginsberg, Western Reserve University, School of Medicine, Cleveland, Ohio.

J. E. Smadel, National Institutes of Health, Bethesda, Md.

NEW MEMBERS

Elected January 24, 1957

SUSTAINING MEMBERSHIP

Lamb, Henry Douglas, M.D., Biochemistry. Assistant Professor, Neurology, University of Minnesota, Minneapolis, Minn.

Mishoe, Luna Isaac, Ph.D., Eigenfunction. Acting Head, Department of Physics, Morgan State College, Baltimore, Md.

Rashevsky, Nicholas, Ph.D., Biology. Professor, Mathematics, The University of Chicago, Chicago, Ill.

Santos, Francisco O., Ph.D., Chemistry, Professor, College of Agriculture, University of The Philippines, Laguna, Philippines.

Schaible, Druska Carr, M.S., Biology. Professor, Biological Science, University of Alaska, Fairbanks, Alaska.

Slick, Thomas Baker, D.Sc., Medicine. Chairman of Board, Slick Oil Corporation, Houston, Texas.

Struthers, Alfred Morgan, M.D., Medicine. Private Practice, Syracuse, N.Y.

Tucker, Ralph W., M.Ed., Psychotherapy. Director, Rehabilitation Services, Seaside Psychiatric Clinic, Modesto, Calif.

ACTIVE MEMBERSHIP

Abe, Kyuji, Dr. Pharm., Pharmacy. Vice-Head, Tokyo Research Laboratory, Tokyo Imperial University, Tokyo, Japan.

Abramson, Julius, M.D., Cardiology. Private Practice, Boston, Mass.

Adamson, Robert E., Ph.D., Psychology. Assistant Professor, Emory University, Emory University, Ga.

Afonsky, Dimitri A., Ph.D., Biology. Research Associate, Colgate-Palmolive Co., New Brunswick, N.J.

Baggett, Billy, Ph.D., Biochemistry. Instructor, Harvard Medical School, Harvard University, Cambridge, Mass.

Barros, Roberto, D., M.D., Biology. Professor of Biology, Chilean University, Santiago, Chile.

Beaulieu, Richard, M.D., Biology. Fellow, Plastic Surgery, Manhattan Eye, Ear and Throat Hospital, New York, N.Y.

Bell, Paul H., Ph.D., Biochemistry. Head, Biochemistry Department, Lederle Laboratories, Pearl River, N.Y.

Benacerraf, Baruk, M.D., Pathology. Assistant Professor, Pathology, New York University Medical School, New York, N.Y.

Benitz, Karl-Friedrich, M.D., Pathology. Pathologist, American Cyanamid Co., Pearl River, N.Y.

Bindler, Elliot H., A.B., Physiology. Student, State University of New York, Brooklyn, N.Y.

Birns, Monroe, M.D., Pathology. Instructor, Albert Einstein College of Medicine, New York, N.Y.

Bloom, Henry Harold, M.S., Bacteriology. Lieutenant, United States Navy, Lansing, Mich.

Boyd, Theodore E., Ph.D., Poliomyelitis. Assistant Director, Research National Foundation for Infantile Paralysis, New York, N.Y.

Bracken, Everett C., Ph.D., Microbiology. Assistant Professor, Vanderbilt University, Nashville, Tenn.

Brannin, Richard S., B.S.E.E., Biology. Staff, Sperry Gyvoscope Co., Lake Success, N.Y.

Brin, Myron, Ph.D., Biochemistry. Chief Biologist, Food Research Laboratories, Long Island City, N.Y.

Brown, Arthur, Ph.D., Microbiology. Branch Chief, V.R. Division, Fort Detrick, Frederick, Md.

Brown, Kenneth L., M.S., Economic History. Director, Advertising, Wyeth Laboratories, Inc., Philadelphia, Pa.

Brunish, Robert, Ph.D., Biochemistry. Research Assistant, University of California, Los Angeles, Calif.

Byron, Joseph Winston, M.S., Pharmacology. Associate, Pharmacology, Roswell Park Memorial Institute, Buffalo, N.Y.

Cailleau, Relda, D.Sc., Biochemistry. Assistant Research Biochemist, University of California Medical Center, San Francisco, Calif.

Carman, P.E., B.S., Pharmaceuticals. Executive Director, Research, S.E., Massengill Co., Bristol, Tenn.

Carver, David H., M.D., Infectious Diseases. Research Fellow, Cleveland City Hospital, Cleveland, Ohio.

Castellano, Gabriel Angelo, Ph.D., Virology. Student, Kansas State College, Manhattan, Kans.

Cavanaugh, Margaret W., Ph.D., Cytology. Histologist, Southeast Louisiana Hospital, Mandeville, La.

Cerf, Jean A., M.D., Neurophysiology. Anatomist, Brussels University, Brussels, Belgium.

Chacko, Liza W., Ph.D., Anatomy. Professor, All Indian Institute Medical Sciences, Sufdarjung, New Delhi, India.

Cheng, Lorraine H. L., M.S., Biochemistry. Research Assistant, Charles Pfizer & Co., Maywood, N.J.

Christiansson, Bengt, Ph.D., Pharmacology. Scientific Representative of AB ASTRA, Sweden, New York, N.Y.

Chu, Liang-Wei, Ph.D., Virology. Research Associate, University of Michigan, Ann Arbor, Mich.

Chu, Tse-Wei, M.S., Cytology. Research Associate, University of Pennsylvania, Philadelphia, Pa.

Cianciulli, Arnold E., B.S., Psychology. Student, Rutgers University, Newark, N.J.

Clowes, George Henry Alexander, Jr., M.D., Cardiovascular Surgery. Assistant Professor, Surgery, Western Reserve University, Cleveland, Ohio.

Colovos, Nicholas F., M.S., Animal Nutrition. Animal Nutritionist, University of New Hampshire, Durham, N.H.

Concannon, Joseph, M.S., Parasitology. Student, St. Johns University, Brooklyn, N.Y.

Conrad, Eugene A., Ph.D., Cellular Pharmacology. Instructor, Bowman Gray School of Medicine, Winston-Salem, N.C.

Cox, Rody Powell, M.D., Internal Medicine. Chief, Medical Resident, Hospital of the University of Pennsylvania, Philadelphia, Pa.

Cumming, Edith, L.W., Bacteriology. Vice-President, Carworth Farms, Inc., Valley Cottage, N.Y.

Daniels, Richard Alan, M.D., Medicine. Resident Physician, Bronx V.A. Hospital, New York, N.Y.

De Pape, Albert J., M.D., Biology. Research Assistant, Manitoba Medical College, Norwood, Manitoba, Canada.

Dillenberg, Hermann O., M.D., Epidemiology. Medical Adviser, CIBA Co. of Canada, Montreal, P.Q., Canada.

Di Paolo, Joseph A., Ph.D., Oncology. Research Scientist, Roswell Park Memorial Institute, Buffalo, N.Y.

Dobkin, Allen B., M.D., Pharmacology. Assistant Professor, University of Saskatchewan, Saskatoon, Sask., Canada.

Draper, Harry R., M.D., Psychiatry. Private Practice, Philadelphia, Pa.

Drury, George L., M.S., Microbiology. Instructor, Biology, Weston College, Weston, Mass.

Ehrenkranz, N. Joel, M.D., Infectious Diseases. Assistant, Medicine, Boston University School of Medicine, Boston, Mass.

Elias, Arthur W., B.S., Atherosclerosis. Research Pharmacologist, Warner-Chilcott Laboratories, Morris Plains, N.J.

Evans, Edward S., Jr., Ph.D., Endocrinology. Instructor, Anatomy, University of California, Berkeley, Calif.

Feinstein, Alvan R., M.D., Rheumatic Fever. Assistant Medical Director, Irvington House, New York, N.Y.

Finkel, Miriam Posner, Ph.D., Radiobiology. Associate Scientist, Argonne Laboratory, Lemont, Ill.

Fletcher, Dean C., Ph.D., Biochemistry. Biochemist, E.I. du Pont de Nemours & Co., Wilmington, Del.

Frauenpreis, Carol, Medicine. Student, Douglass College, New Brunswick, N.J.

Friedman, Samuel L., B.S., Pharmacology. Teaching Assistant, Columbia University, New York, N.Y.

Frost, John K., M.D., Cytology. Associate Professor, University of Maryland, College Park, Md.

Friedrich, William, Dr. T.S., Civil Engineering. In Charge, Foreign Affairs, Vitro Company, New York, N.Y.

Funaro, Vincent Michael, B.S., Oral Surgery. Student, University of Pennsylvania, Philadelphia, Pa.

Gaddum, John Henry, F.R.S., Pharmacology. Professor, Pharmacology, University New Buildings, Teviot Place, Edinburgh, Scotland.

Gelfand, Morrie M., M.D.C.M., Obstetrics. Attending Obstetrician, Jewish General Hospital, Montreal, P.Q., Canada.

Glenister, David, A.B., Teaching Assistant, Department of Biology, Princeton University, Princeton, N.J.

Gollan, Frank, M.D., Physiology. Assistant Director, V.A. Hospital, Nashville, Tenn.

Gonshorek, Mary F., B.A., Bacteriology. Senior Bacteriologist, The New York Department of Health, New York, N.Y.

Goscienski, Philip J., B.S., Biology. Laboratory Instructor, Fairfield University, Fairfield, Conn.

Goss, Albert E., Ph.D., Human Learning. Professor, Psychology, University of Massachusetts, Amherst, Mass.

Greene, Elias L., B.S., Virology. Research Assistant, Sloan-Kettering Institute, New York, N.Y.

Griffith, Bezaleel Herald, M.D., Plastic Surgery. Research Fellow, Cornell University, New York, N.Y.

Griffith, Francis Willard, B.A., Food Chemistry. Executive Vice-President, The Griffith Laboratories, Inc., Newark, N.J.

Gronwall, Anders, M.D., Biochemistry. Professor, University Hospital, Uppsala, Sweden.

Hall, Ross H., Ph.D., Biochemistry. Research Chemist, Lederle Laboratories Division, American Cyanamid Co., Pearl River, N.Y.

Hanna, Azmi Robia, M.P.H., Epidemiology. Instructor, University of Alexandria, Alexandria, Egypt.

Harms, Ernest, Ph.D., Psychiatry. Editor, Journal of Child Psychiatry, New York, N.Y.

Hartig, William John, M.S., Protozoan Physiology. Instructor, St. Johns University, Brooklyn, N.Y.

Herschman, Arthur, Ph.D., Nuclear Physics. Physicist, Quartermaster Food & Container Institute for the Armed Forces, Chicago, Ill.

Hess, Helen H., M.D., Neurochemistry. Assistant Neuropathologist, McLean Hospital, Belmont, Mass.

Hollis, John C., Machine Tooling, Chief, Engineer, Morey Machinery Co., Long Island City, N.Y.

Hope, Justin Morrill, M.D., Biology. Chief, Psychiatry, New England Center Hospital, Boston, Mass.

Hough, Charles E., M.D., Pharmaceuticals. Staff, Charles Pfizer & Co., Inc., Brooklyn, N.Y.

Howell, David S., M.D., Arthritis. Director, Arthritis Service, University of Miami, Miami, Fla.

Isley, John K., Jr., M.D., Medicine. Associate Radiologist, Duke University Hospital, Durham, N.C.

Itkin, Arthur G., M.S., Mathematics. Assistant Statistician, Merck & Co., Inc., Rahway, N.J.

Ivey, William D., Ph.D., Embryology. Assistant Professor, Alabama Polytechnic Institute, Auburn, Ala.

James, George, M.D., Public Health. Deputy Commissioner of Health, The New York City Department of Health, New York, N.Y.

Jones, Mary H., M.S., Virology. Laboratory Technician, University of Michigan, Ann Arbor, Mich.

Kail, Frederick J., M.D., Immunology. Director, Austrian State Serum Institute, Vienna, Austria.

Katz, Sidney, M.D., Anesthesiology. Chief, Anesthesiology. Mount Sinai Hospital, Cleveland, Ohio.

Keeffee, Mary Margaret, Ph.D., Cytology. Associate Professor, Biology, Rhode Island College of Education, Providence, R.I.

Kenney, Robert M., D.V.M., Veterinary Medicine. Private Practice, Springfield, Vt.

King, Frederick Alexander, Ph.D., Psychology. Instructor, Ohio State University, Columbus, Ohio.

Klein, Theodore U., B.S., Medical Writing. Medical Writer, Paul Klemtner & Co., Newark, N.J.

Klingel, Harry, Chemistry. Director, Research, Fine Chemical Division, Shulton Inc., Madison, N.J.

Korol, Bernard, Ph.D., Cardiovascular Research. Senior Pharmacologist, Smith, Kline & French Laboratories, Philadelphia, Pa.

Krcmery, Emil, M.D., Medicine. Private Practice, Cicero, Ill.

Kuperman, Albert S., Ph.D., Pharmacology. Graduate Student, Cornell University Medical College, Woodside, N.Y.

Kutner, Leon J., Ph.D., Virology. Research Associate, Sloan-Kettering Institute, New York, N.Y.

Labalme, George, M.D., Biology. Private Practice, New York, N.Y.

Laird, Raymond L., Sc.D., Parasitology. Chief Malariologist, I.C.A. to Indonesia, Department of State, Washington, D.C.

Landahl, Herbert D., Ph.D., Mathematical Biology. Professor, Biology. University of Chicago, Chicago, Ill.

Langdon, Ladema Mary, Ph.D., Biology. Professor, Goucher College, Baltimore, Md.

Leeson, Gerald, A.B., Biochemistry. Research Associate, Warner-Chilcott Laboratories, Morris Plains, N.J.

Levine, Seymour, Ph.D., Psychology. Research Psychologist, Ohio State University, Columbus, Ohio.

Lipson, Martha, M.D., Pediatrics. Research Fellow, Department of Pediatrics, City Hospital, Cleveland, Ohio.

Livingston, Gideon E., Ph.D., Food Chemistry. Assistant Professor, Amherst College, Amherst, Mass.

Luchsinger, Peter C., M.D., Cardiopulmonary Physiology. Assistant Director, Physiology Laboratory, District of Columbia General Hospital, Washington, D.C.

Luginbuhl, Roy E., M.S., Animal Viruses. Assistant Professor, Animal Diseases, University of Connecticut, Storrs, Conn.

McCluskey, Robert T., M.D., Renal Disease. Associate Professor, Pathology, New York University, College of Medicine, New York, N.Y.

McCullough, Willard G., Ph.D., Biochemistry. Associate Professor, Microbiology, Wayne State University, Detroit, Mich.

McDonnell, William V., M.D., Pathology. Associate Professor, Jefferson Medical College, Philadelphia, Pa.

McLaren, Leroy Clarence, Ph.D., Virology. Assistant Professor, University of Minnesota, Minneapolis, Minn.

McLean, Donald Millis, M.D., Virology. Senior Medical Officer, Department of Health, Commonwealth of Australia, Melbourne, Australia.

Macko, Edward, B.A., Pharmacology. Senior Scientist, Smith, Kline & French Laboratories, Philadelphia, Pa.

Macom, J. Morgan, Jr., D.D.S., Dental. Assistant Director, Clinical Research, New Brunswick, N.J.

Madhosingh, Clarence, B.S.A., Mycology. Graduate Student, University of Western Ontario, London, Ont., Canada.

Marcus, David, M.D., Medicine. Private Practice, Brooklyn, N.Y.

Mattiat, Oskar E., Dr. Eng., Physics. Section Head, Clevite Research Center, Cleveland, Ohio.

Maxfield, Mary Evans, A.B., Physiology. Associate Professor, Woman's Medical College of Pennsylvania, Philadelphia, Pa.

Mechner, Francis, Ph.D., Psychology. Psychologist, Schering Corporation, Bloomfield, N.J.

Meiklejohn, William H., M.S., Magnetism. Physicist, Research Laboratory, General Electric Company, Schenectady, N.Y.

Millen, Maurice, M.D., Medicine. Private Practice, Boston, Mass.

Miller, Glenn H., Ph.D., Physical Chemistry. Assistant Professor, University of California, Santa Barbara, Calif.

Miller, I. Franklin, D.D.S., Dentistry. Private Practice, New York, N.Y.

Mills, Kenneth S., Ph.D., Bioelectric Potentials. Instructor, University of California, Los Angeles, Calif.

Montgomery, John A., Ph.D., Organic Chemistry. Head, Chemistry Division, Southern Research Institute, Birmingham, Ala.

Morris, Horton H., M.S., Organic Chemistry. Research Director, Southern Clays, Inc., Gordon, Ga.

Mueller, George E., Ph.D., Physics. Professor, Electrical Engineering, Ohio State University, Columbus, Ohio.

Mullins, John D., Ph.D., Chemistry. Research Associate, Merck, Sharp & Dohme, West Point, Pa.

Myers, Orlo E., Ph.D., Physical Chemistry. Senior Scientist, Convair Science Research Laboratory, San Diego, Calif.

Myers, Peter B., Ph.D., Physics. Staff, Bell Telephone Laboratories, Murray Hill, N.J.

Naistat, Samuel S., Ph.D., Chemistry. Assistant Manager, Becco Chemical Divivison, Station B, Buffalo, N.Y.

Nathaniel, Arthur, M.B., Opthalmology. Research Fellowship, New York University, New York. N.Y.

Nathans, Marcel W., Ph.D., Chemistry. Associate Chemist, Argonne National Laboratories, Lemont, Ill.

Neustein, Harry B., M.D., Pathology. Instructor, University of Colorado, Denver, Colo.

Nichaman, Milton Zalman, A.B., Endocrinology. Student, Tufts University, Boston, Mass.

Nodot, Andre Pierre, M.D., Pediatrics. Exchange Visitor, Babies Hospital, Columbia-Presbyterian Medical Center, New York, N.Y.

Nusbaum, Murray L., M.D., Medicine Senior Gynecologist, St. Elizabeth Hospital, Utica, N.Y.

O'Brien, Thomas Emmet, Ph.G., Internal Medicine. Executive Secretary, Neurology Study Section, National Institutes of Health, Bethesda, Md.

O'Connor, Denis S., M.D., Surgery. Orthopedic Surgeon, Private Practice, New Haven, Conn.

Odor, D. Louise, Ph.D., Electron Microscopy. Assistant Professor, University of Florida, Gainesville, Fla.

Offutt, Edward P., Ph.D., Microbiology. Executive Secretary, Grants Advisory Committee, Philadelphia, Pa.

Oró, John F., Ph.D., Biochemistry. Assistant Professor, University of Houston, Houston, Texas.

Orr, William J., M.D., Medicine. Private Practice, Buffalo, N.Y.

Osterhout, Suydam, M.D., Infectious Diseases. Graduate Fellow, Rockefeller Institute for Medical Research, New York, N.Y.

Otenasek, Frank J., M.D., Neurosurgery. Neurosurgeon, Baltimore, Md.

Padnos, Morton, M.S., Protozoology. Director, Protista Research Laboratory, Levittown, L.I., N.Y.

Palazzi, Duccio, M.D., Histopathology. Head, Department of Pathology, Hospital S. Gerardo dei Tintori di Monza, Milano, Italy.

Palincsar, Edward E., M.S., Microbiology. Teaching Assistant, Northwestern University, Evanston, Ill.

Parker, Basil W., Ph.D., Biology. Professor, Lehigh University, Bethlehem, Pa.

Paul, Anthony, B.S., Biology. Senior Student, Chiropractic Institute of New York, New York, N.Y.

Pearce, Louise, M.D.. Pathology. Retired, Belle Mead, N.J.

Peniche, Julio Hernandez, M.D., Neurology. Head, Hospital de Enefermedades de la Nutrición, México, D.F. México.
Philippu, Athineos J., M.D., Physiology. Laboratory of Physiology, University of Athens, Athens, Greece.
Pitesky, Isadore, M.D., Allergy. Allergist, Private Practice, Long Beach, Calif.
Poole, John B., Ph.D., Parasitology. Parasitologist, Sterling-Winthrop Research Institute, Rensselaer, N.Y.
Potter, Paul H., M.D., Pathology. Resident, Pathology, St. Luke's Hospital, Duluth, Minn.
Potts, Gordon O., Ph.D., Endocrinology. Endocrinologist, Sterling-Winthrop Research Institute, Rensselaer, N.Y.
Powell, Wilson Frederick, M.D., Pathology. Research Fellow, Yale University, New Haven, Conn.
Priddy, Ralph B., Ph.D., Biology. Assistant Professor, Zoology, University of Pittsburgh, Pittsburgh, Pa.
Prier, James E., Ph.D., Virology. Head, Biological Development, Sharp & Dohme Co., Inc., West Point, Pa.
Pritchard, Walter Herbert, M.D., Clinical Cardiovascular. Associate Professor, Western Reserve University, Cleveland, Ohio.
Rankin, A. Donald, M.S., Veterinary Clinical Investigation. Associate Medical Director, Squibb Institute for Medical Research, New Brunswick, N.J.
Rees, Searle B., M.D., Metabolism. Research Fellow, Peter Bent Brigham Hospital, Boston, Mass.
Reeve, Ernest Basil, B.Ch., Chemical Physiology. Associate Professor, University of Colorado, Denver, Colo.
Reid, Arthur W., Ph.D., Physics & Chemistry. Associate Professor, Pharmacy Administration, Ferris Institute, Big Rapids, Mich.
Riesen, Austin H., Ph.D., Experimental Psychology. Professor, Psychology, The University of Chicago, Chicago, Ill.
Rigney, Thomas G., M.D., Medicine. Physician, Standard Oil Company, New York, N.Y.
Rigopoulos, Nicholas, B.S., Bacteriology. Research Technician, Wellcome Research Laboratories, Tuckahoe, N.Y.
Ritchie, Malcolm L., Ph.D., Psychology. President, Ritchie & Associates, Inc., Chicago, Ill.
Rivadeneira, Juan C., M.D., Infectious Diseases. Research Fellow, Western Reserve University, Cleveland, Ohio.
Romano, Marie, A.B., Bacteriology. Bacteriologist, The New York City Department of Health, New York, N.Y.
Ron, Alan, M.D.C.M., Pediatrics. Physician, Montreal Childrens Hospital, Montreal, P.Q., Canada.
Rosenthall, Charles E., M.D., Medicine. Private Practice, Somerville, Mass.
Sacher, George A., Jr., B.S., Biology. Biologist, Argonne National Laboratory, Lemont, Ill.
Sagen, Harry E., Ph.D., Bacteriology. Manager Production Quality Control Division, Abbott Laboratories, North Chicago, Ill.
Salanitre, Ernest, M.D., Anesthesiology. Associate, Anesthesiology, Columbia University, New York, N.Y.
Salter, Lawrence C., Pediatrics. Secretary, Playtex Park Research Institute, New York, N.Y.
Sanders, Aaron P., M.S., Biophysics. Director, Radioisotope Laboratory, Duke University, Durham, N.C.
Santina, Henry, M.D., Pathology. Resident, St. Joseph's Infirmary, Atlanta, Ga.
Sartwell, Philip E., M.D., Epidemiology. Professor, The Johns Hopkins University, Baltimore, Md.
Sauberlich, Howerde E., Ph.D., Nutrition. Animal Nutritionist, Alabama Polytechnic Institute, Auburn, Ala.
Sauer, William George, M.D., Medicine. Consultant, Mayo Clinic, Rochester, Minn.
Saunders, Allen P., Ph.D., Biology. Group Leader, Abbott Laboratories, North Chicago, Ill.
Saunders, Richard Lorraine de Chasteney Holbourne, M.D., Anatomy. Professor, Dalhousie University, Halifax, N.S., Canada.
Sautter, Jay H., Ph.D., Pathology. Head, Division of Pathology, University of Minnesota, St. Paul, Minn.

Savino, P.R., M.D., Medicine. Associate Professor, Marquette University, Milwaukee, Wis.

Schacht, Franklin L., Ph.D., Bacteriology. Milk Sanitarian, State Department of Health, Albany, N.Y.

Schaefer, Arnold E., Ph.D., Biochemistry. Executive Director, Nutrition for National Defense, National Institutes of Health, Bethesda, Md.

Schaeffer, Robert L., Jr., Ph.D., Taxonomy. Assistant Professor, Biology, Muhlenberg College, Allentown, Pa.

Schaeffer, William D., M.D., Chemistry. Assistant Director, National Printing Ink Research Institute, Lehigh University, Bethlehem, Pa.

Schenck, Harry P., M.D., Otorhinolaryngology. Professor, Otolaryngology, University of Pennsylvania, Philadelphia, Pa.

Scherp, Henry W., Ph.D., Microbiology. University of Rochester, Rochester, N.Y.

Schireson, Sylvan, D.D.S., Dentistry. Assistant Professor, University of Southern California, Los Angeles, Calif.

Schmale, Arthur H., Jr., M.D., Psychophysiology. Instructor, Medicine, University of Rochester, Rochester, N.Y.

Schmid, Marie K., A.B., Biology. Assistant, Technical Director, Warner-Lambert Pharmaceutical Company, Morris Plains, N.J.

Schmidt, Donald Arthur, D.V.M., Pathology. Instructor, Michigan State University, East Lansing, Mich.

Schmidt, Nathalie, John, Ph.D., Virology. Research Microbiologist, State Department of Health, Berkeley, Calif.

Schmidt-Nielsen, Bodil, Dr. Phil., Water Metabolism. Senior Research Associate, Duke University, Durham, N.C.

Schneiderman, Howard A., Ph.D., Radiobiology. Associate Professor, Zoology, Cornell University, Ithaca, N.Y.

Schneiderman, Marvin A., M.A., Mathematics. Mathematical Statistician, National Cancer Institute, National Institutes of Health, Bethesda, Md.

Schoch, Henry K., M.D., Internal Medicine. Chief, Medical Service, V.A. Hospital, Ann Arbor, Mich.

Schrack, William D., Jr., M.D., Public Health. Director, Division of Communicable Disease Control, Pennsylvania Department of Health, Harrisburg, Pa.

Schuler, Werner, Dr. Med. Biochemistry. Professor, CIBA Limited, Basle, Switzerland.

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